Forefoot disorders

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Definitions, treatment and outcome measurement

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CONTENT

Chapter 1

Introduction and aims

I. INTRODUCTION AND AIMS

The present thesis describes different aspects of forefoot problems. These problems receive minor attention in medical literature, certainly if you consider the high prevalence coupled with impaired mobility, as reported in the following. A Dutch survey among a general population revealed that 9% had suffered from foot pain over the last 12 months; in 5% these complaints were chronic (31). These numbers match with those found in a study performed in the UK, describing that complaints of foot pain make up 8% of all musculoskeletal lower extremity consultations of general practitioners (25). The prevalence increases with age. Recent studies report a prevalence of foot problems for people aged 50 years and older ranging from 15 to 42% (39). The most expressed symptom is foot pain (60%) and most foot pain occurs in the forefoot (34,38). A study performed by Gorter et al. reports that the estimated prevalence of non-traumatic foot complaints among the Dutch population, aged above 65 years, ranges from 19 to 21%(13). The prevalence is higher among females (1 out of 4) than males (1 out of 7)(13). They describe that about 65% of the persons with foot pain experience limitations in daily activities and mobility (13).

Different forefoot disorders may be the cause of forefoot pain (1)(6)(7)(19). These include vascular, neurogenic, dermatologic and musculoskeletal problems. In general, the term metatarsalgia has been adopted to define forefoot pain of any cause (2,5)(10,11,14)(20). In analogy to metatarsalgia, the term peri-arthritis-humero-scapularis (PHS) has been used as a garbage bin describing all types of shoulder pain. This is no longer acceptable and based on history and careful clinical examination usually a more precise diagnosis can be established. In this thesis metatarsalgia is defined as pain on the plantar aspect of one or more of the metatarsal heads, as a result of biomechanical overload of the soft tissues. This overload usually results in callus formation. Several disorders may lead to biomechanical overload of the forefoot, as will be described later. Thus, metatarsalgia should be distinguished from pain, for example, caused by arthritic joints, neurogenic pain (like Morton's neuralgia) and complaints for which a clear cause cannot be provided.

Multiple deformities are known to cause increased forefoot pressure resulting in pain. These include malalignment of the hallux, with pain on the medial aspect of the 1st ray and pressure points between the hallux and the lesser toe(s) (7,23,28,29). Likewise an increase of pressure resulting in a bunion and/or callosity can occur on the lateral side of the 5th metatarsal. Such pressure is induced by the combination of widening of the foot and footwear. Deformity of one or more lesser toes can be the cause of increased pressure resulting in painful callosities, corns and ulceration between toes and footwear, between toes and the floor surface or between the toes themselves. The relationship between hallux valgus, arthritis (synovitis) of the metatarsophalangeal joints, lesser toe deformity and metatarsalgia is extensively described in **Chapter 5** and **the Addendum** of this thesis.

The scientific research and discussion of this thesis, as described in the subsequent chapters, are focussed on lesser toe deformities and rheumatoid forefoot deformity.

II. DEFINITIONS

It is hypothesized that a hammer and claw toe are different stages in the same pathophysiological process. The key factor in the development of hammer and claw toes is thought to be the metatarsophalangeal (MTP) joint (22). Disturbed balance between intrinsic and extrinsic muscles of the foot and lower leg can result in progressive extension of the joint. In case of hammer toe deformity, the extended position of the MTP joint is flexible and the accompanying flexed position of the proximal interphalangeal (PIP) joint is more pronounced and most often rigid. In case of extension contracture of the MTP joint the deformity is defined as a claw toe. The fixed extended position of the MTP joint (and certainly in cases with dorsal MTP joint dislocation) causes biomechanical plantar overload [Figures 1a and 1b]. The unfavorable imbalance of forces, actually, enforces progression of the deformity. Callus, pain and progressive toe deformity may develop.

Figure 1a. Hyperextension deformity at the MTP joint will gradually lead to distal and dorsal dislocation of the plantar plate in relation to the MT head.

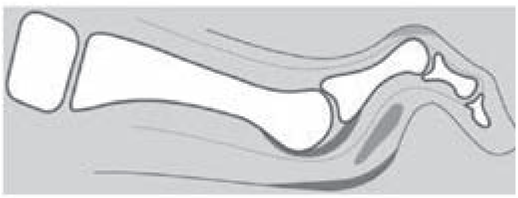
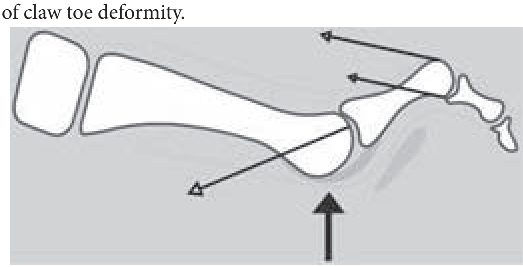


Figure 1b. Increase (in stance) of plantar pressure on the MT head resulting from pull by the extensor and flexor tendons in a case of claw toe deformity.



Other causative factors may lead to MTP joint imbalance, as is the case if progressive synovitis exists in patients with rheumatoid arthritis (18). The synovitis causes distention of the MTP joint capsule and ligaments. Eventually, with progressive thinning of the plantar soft tissues, the plantar plate can rupture and the MT head may 'herniate' through the plantar joint capsule. Actually it is not the MT head that changes its position, but it is the toe that hyperextends and moves dorsally in relation to the MT head. The excessive extended position of the MTP joint brings along dislocation of the plantar fat pad and even more relative thinning of the plantar soft tissues. Pain as result of synovitis of the MTP joints is often the initial symptom of rheumatoid arthritis (24,26,36). In later stages of the disease the pain is most often caused by the deformity that has developed, secondary to the arthritic process. The relatively more prominent MT heads result in increased biomechanical stress on the attenuated soft tissue, and therefore plantar callosities and/or large bursae can develop. Consequently, this will result

Figure 2a. Claw toe deformity of the lesser rays and a rheumatoid nodule on the medioplantar aspect of the first MT head.

Figure 2b. Plantar aspect of rheumatoid forefoot deformity, with typical overload.

in metatarsalgia with impaired walking ability [Figures 2].

Stainsby noted that, from a pathomechanical point of view there is in fact no difference between a severe claw toe deformity in non-rheumatoid and rheumatoid patients (33). This justifies a uniform treatment protocol of these MTP joint deformities.

III. OUTCOME MEASUREMENT

Different conservative and operative treatment options exist regarding lesser toe and MTP joint deformities (15,21). In order to evaluate the efficacy of the different procedures outcome assessment is critical (3,17). Within this view, one should strive for standardized and validated outcome measures. These should be patient-based and encompass items important for the patient (30). These measures are referred to as *Patient Reported Outcome Measures (PROMs).*

These PROMs should preferably be combined with objective parameters, as regarded by the treating physician.

Currently, PROMs are of increasing significance and more and more applied in practice, for various reasons, i.e. requests by insurance companies, assessment of quality of care and scientific evaluation. Most literature on outcome measurement after treatment of forefoot disorders is focussed on outcome after hallux valgus surgery (3). Various questionnaires have been developed (9). The psychometric value of these questionnaires is often unclear. Few specific PROMs, directed at forefoot complaints, have been reported in literature. Standardisation of outcome measurement, with validated tools, as part of patient-centred high quality of care, is, however, imperative. A clear guideline on these outcome tools would enable more consistent reporting of outcomes.

IV. OUTLINE OF THIS THESIS

The main goal of this thesis is to create uniformity in the evaluation, treatment and outcome measurement of certain patterns of forefoot disorders. This thesis specifically focuses on lesser toe deformity and rheumatoid forefoot deformity. First, current standards, found in literature and Dutch orthopaedic practice, are described. Thereafter the outcome of different treatment modalities are shown. Finally, different aspects of outcome measurement are assessed.

First of all an evaluation of national orthopaedic standards concerning hammer toe, claw toe and mallet toe was performed. Evaluation of current standards is required to detect contradictions and differences. From there consensus may be reached.

A questionnaire was designed which addressed adopted definitions and (postoperative) treatment protocols. This questionnaire was sent to all 101 Dutch departments of orthopaedic surgery (Chapter 2).

Question 1. *Is there any consensus on definition and treatment of lesser toe deformities in Dutch orthopaedic practice?*

Then, it was deemed important to assess the level and quality of national standards through comparison with the scientific literature. Within this perspective a research of literature was performed on different used definitions of hammer toe, claw toe and mallet toe (Chapter 3). Subsequently, the authors proposed a specific definition for each deformity, which may be generally applied. Uniformity is essential in communication on diagnosis and treatment of these lesser toe deformities.

Question 2. *What are the general accepted definitions for hammer, claw and mallet toe?*

In case conservative treatment fails, surgery of lesser toe deformities can be an option. These operative procedures are among the most commonly conducted interventions in general orthopaedic practice (12). Numerous surgical procedures have been described for the correction of hammer and claw toe deformity (8). The classic surgical techniques include PIP joint resection and PIP joint fusion (4). The results of these procedures, as described in literature, are rather variable (4). It is still unknown which of these procedures has the best clinical results. In Chapter 4 the results of a randomized clinical trial comparing PIP joint resection and PIP joint fusion, regarding treatment of claw toe deformity, are described.

Question 3.*Is there a difference in outcome between PIP joint resection and PIP joint fusion treating patients with PIP joint flexion deformity*

As explained previously, toe deformity as a result of rheumatoid arthritis may result in biomechanical overload of the forefoot (metatarsalgia). Despite, impressive improvement of the efficacy of pharmacological treatment of rheumatoid arthritis, severe forefoot deformity among this patient population still exists. The foot is commonly affected at early stages of the disease, with a prevalence of up to 90% for the MTP joints, and in 15% of the cases forefoot complaints are the first manifestation of the disease (27,35). So, awareness of forefoot involvement in the early stages of the disease is important to maintain optimal function and prevent disability (32). Up to 81% of patients with rheumatoid arthritis may suffer from forefoot problems (24). Soft tissue instability and joint destruction results in hallux valgus, dislocation of the lesser toes and displacement of the plantar fat pad, with associated metatarsalgia. The resultant foot deformity and pain adversely affect activities of daily living and the quality of life (36,37).

Chapter 5 is a review of current standards and scientific data on rheumatoid forefoot disorders.

Question 4.*Is there consensus on diagnosis and treatment of rheumatoid forefoot deformity in literature?*

If conservative treatment of patients, suffering from rheumatoid forefoot deformity, does not result in an acceptable situation, surgery has a role. Resection of the metatarsal heads (MTH), as described by Hoffmann in 1912 for clawed toes, is still regarded as the standard treatment (16,40). In course of time, various modifications of this original procedure have been developed. The results, particularly long-term results, after these different MTH procedures are rather varying.

Improvement of medicinal treatment of rheumatoid arthritis, with possible reduction of joint destruction, may support less radical surgery, with preservation of the functional status (saving the MTP joints). Chapter 6 demonstrates the results of a randomized clinical trial comparing an operative technique with MTH resection, with a technique in which the MTP joint is preserved.

Question 5.*Is there a difference in outcome between MTP joint resection or preservation in the treatment of rheumatoid forefoot deformity?*

When assessing the outcome after treatment of forefoot problems, recently emphasis is put on patient-based outcome, measured through so-called Patient Reported Outcome Measurement (PROMs). Regarding forefoot problems, primarily outcome tools directed at hallux valgus are described and applied in literature. In order to evaluate treatment results, outcome measurement should be standardized. Solid evaluation of treatment effect warrants a reliable, valid and patient-based outcome tool and it should be directed at the outcome of interest. Chapter 7 presents an overview of the literature of the current available and adopted outcome measurement tools regarding hallux valgus. The quality is assessed through evaluation of so-called psychometric properties. A proposal for most suitable PROM is proposed.

Question 6. *What is the most appropriate PROM measuring outcome after treatment of hallux valgus?*

PROMs can be obtained through various methods, with variation in costs, convenience and availability. It is unclear which method promotes highest response rate and is most suitable in daily practice. Chapter 8 demonstrates the results of different methods of obtaining PROMs.

Question 7. *Which method of obtaining a PROM results in highest response rate?*

The addendum includes an extensive description of the aetiology, anatomy, biomechanics, pathophysiology, symptoms, diagnosis and treatment, concerning lesser toe deformities.

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Chapter 2

Opinions on Lesser Toe Deformities Among Dutch Orthopaedic Departments.

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ABSTRACT

Background: Wide variations in definitions of lesser toe deformities exist. In addition, a general consensus regarding treatment of lesser toe deformities is lacking. The objective of this study was to evaluate of the definitions, current concepts, and treatment protocols for lesser toe deformities among orthopaedic departments in The Netherlands.

Methods: A questionnaire with statements regarding lesser toe deformities was sent to all 101 Dutch departments of orthopaedic surgery.

Results: In total 76 (75%) completed forms were analyzed. A wide variation regarding definitions, concepts, and treatment strategies of lesser toe deformities was reported among the Dutch orthopaedic departments. Only half of all responding departments had a protocol or consensus in the treatment.

Conclusions: The definitions of lesser toe deformities used in Dutch orthopaedic departments do not coincide. This might explain the variations in indications and the various performed interventions for different deformities. The differences of opinion among the Dutch orthpaedic departments may have important clinical consequences because an indication for surgery depends on the correct diagnosis. To correctly interpret and improve treatment results, a consensus on this topic should be introduced.

Key Words: Clawtoe; Hammertoe; Mallet Toe; Opinions

INTRODUCTION

Most foot problems in the general population consist of symptoms from lesser toe deformities. The reported incidence of hammer toes and claw toes ranges from 2% to 20%.[3,5,9] The literature presents a wide variation in the definitions of lesser toe deformities.[1,8,11,13,16] The definitions of hammer toe, claw toe, and mallet toe have been, and continue to be, the most confusing area of pathology for those involved with foot and ankle care. Coughlin and Mann[4] defined these as, "A hammer toe involves the proximal interphalangeal (PIP) joint; the middle and distal phalanges are flexed on the proximal phalanx. A claw toe involves a hammer toe deformity of the phalanges and dorsiflexion (extension) deformity at the metatarsophalangeal (MTP) joint. A mallet toe involves the distal interphalangeal (DIP) joint; the distal phalanx is flexed on the middle phalanx." Their definitions, however, also are not without some confusion.

Just as for the definitions, problems arise in the treatment of lesser toe deformities. There are many options for correction of lesser toe deformities without a general consensus.[1,2,4–6,13,16] Again, the flow charts of Coughlin and Mann frequently are applied.[4]

The objective of the current study was to evaluate the definitions, concepts, and treatment protocols for lesser toe deformities among the orthopaedic departments in the Netherlands. In this way, uniformity or discrepancy in practice patterns can be evaluated. These results are related to the definitions and treatment protocols of lesser toe deformities as stated by Coughlin and Mann.[4] Uniformity in definitions of lesser toe deformities is mandatory for communication about indications and treatment.

MATERIALS AND METHODS

A questionnaire with statements regarding lesser toe deformities was sent to all 101 departments of orthopaedic surgery in the Netherlands and addressed to orthopaedic surgeons who specialized in foot and ankle surgery. In the cover letter, we asked that the questionnaire be transferred to the correct surgeon if it was sent to a surgeon who did not specialize in foot and ankle surgery. The questionnaire contained five pages with 26 questions and sub-questions. The questions were about definitions, treatment protocols, operative procedures, satisfaction rates and outcomes.

The package contained the questionnaire, a cover letter, and a return envelope. A duplicate package was mailed again after 6 weeks if no response was received. Ten weeks after the original mailing, an e-mail with the questionnaire attached was sent to those who had not responded.

The 101 Dutch orthopaedic departments were located in 123 hospitals. Fifty-four (54%) responded at the first request; after a reminder letter, another 19 departments responded, and after a final e-mail request three additional questionnaires were received.

Data were collected between March and June, 2006. Categorical data and dichotomous variables were summarized as percentages of the responding departments.

RESULTS

A total of 76 (75%; 76 of 101) completed forms were analyzed. Together, these 76 departments represented 404 of the 491 orthopaedic surgeons employed in the Netherlands (82%). On average, a department consisted of five (two to 13) orthopaedic surgeons. All stated percentages referred to common practice in the orthopaedic departments, as expressed by representing surgeons. The percentages did not refer to the opinion of individual surgeons. Residents did not fill out any questionnaire.

In 11% (eight of 76) of the Dutch departments there was a protocol regarding treatment of lesser toe deformities, in 42% (32 of 76) there was consensus among the surgeons in the specific department, and in 47% (36 of 76) there was no reference to the treatment of lesser toe deformities.

There were 30 departments with a residency program. In these departments, 38% of all operative procedures on lesser toe deformities were done by the orthopaedic surgeon, without assistance. Thirty-two percent of all interventions were done by a resident supervised by a staff member. A resident, without supervision, performed 30% of these operative procedures.

Fifty-three percent (40 of 76) of all respondents operated on single-toe deformities in an operating room in an outpatient setting; 22% (17 of 76) also performed interventions on multiple deformities in an outpatient setting. Fifty percent (38 of 76) of all respondents conducted all operations on lesser toe deformities in an operating room in day care.

There was a wide variation in the definitions of hammer, claw, and mallet toes. The results are listed in Table 1. For hammer, claw, and mallet toe, respectively, 24% (18 of 76), 9% (seven of 76), and 70% (53 of 76) were in complete accordance with the Coughlin and Mann[4] definitions. Ninetyfive percent (72 of 76) correctly mentioned PIP joint flexion as an essential characteristic of a hammer toe deformity, but 44% (33 of 76) included MTP joint extension and 58% (44 of 76) DIP joint involvement in the definition. Some (26%; 20 of 76) defined a hammer toe as MTP joint extension with PIP joint flexion and DIP joint extension.

For a claw toe, 78% (59 of 76) defined DIP joint flexion as a characteristic feature; 20% (15 of 76) stated that DIP joint flexion is the single criterion for a claw toe. Forty-four percent included MTP joint extension and 72% (55 of 76) considered PIP joint flexion as part of the definition of a claw toe deformity. Fifty-six percent (43 of 76) incorrectly excluded MTP joint

Table 1:

Opinions (%) on the definitions of hammer toe (definition identical to Coughlin and Mann in bold).

Hammer toe	MTP		PIP		DIP	
	Extension	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**
26%	X			X	X	
24%				**X**		
19%				X	X	
18%	X			X		
8%				X		X
4%						X
1%					X	

Opinions (%) on the definitions of claw toe (definition identical to Coughlin and Mann in bold).

Claw toe	MTP		PIP		DIP	
	Extension	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**
30%				X		X
27%	X			X		X
20%						X
9%	**X**			**X**		
7%	X					
6%				X		
1%	X					X

Opinions (%) on the definitions of mallet toe (definition identical to Coughlin and Mann in bold).

Mallet toe	MTP		PIP		DIP	
	Extension	**Flexion**	**Extension**	**Flexion**	**Extension**	**Flexion**
70%						**X**
9%	X					
7%	X					X
6%				X		
4%				X		X
3%	X			X		
1%	X			X		X

MTP, metatarsophalangeal joint; PIP, proximal interphalangeal joint; DIP, distal interphalangeal joint.

extension in the definition. Thirty percent (23 of 76) described a claw toe as a PIP joint and DIP joint flexion deformity.

Concerning mallet toe, 82% (62 of 76) included DIP joint flexion, 21% (16 of 76) incorrectly included MTP joint extension, and 18% (13 of 76) PIP joint flexion.

For the conservative treatment of lesser toe deformities, 73% (55 of 76) of all responding departments regularly prescribed shoe adaptations, 40% (30 of 76) occasionally used orthoses, and 69% (52 of 76) used special insoles. Fifteen percent (11 of 76) of all respondents indicated surgery after diagnosing the deformity; conservative treatment of lesser toe deformities was no option in these departments. Twenty percent (15 of 76) of all respondents made no distinction between the treatment of a hammer or claw toe deformity; 12% (nine of 76) treated both flexible and rigid deformities equally. Thirty-two percent (24 of 76) of all respondents surgically corrected multiple hammer toes and 37% (28 of 76) multiple claw toes with general anesthesia in an operating room.

Numerous operative procedures were performed for the specific toe deformities. The results are listed in Table 2.

Regarding the choice of a PIP joint arthrodesis or arthroplasty in the treatment of a rigid hammer toe, 30% (23 of 76) preferred an arthrodesis, 63% (48 of 76) a resection arthroplasty, and 7% (five of 76) had no distinct preference. For a rigid claw toe, these percentages were, respectively, 44% (33 of 76), 51% (39 of 76), and 5% (four of 76).

In securing a PIP joint arthrodesis or arthroplasty, 92% (70 of 76) of the respondents used an intramedullary Kirschner wire. Eleven percent (eight of 76) occasionally used an extramedullary pin to temporarily support the joint. In 32% (24 of 76) of all respondents, the Kirschner wire was removed in 2 to 3 weeks postoperatively and in 58% (44 of 76) after 4 weeks. Eighteen percent (14 of 76) removed the Kirschner wire after 6 weeks.

Table 2:

Opinions (%) on the surgical treatment of hammer toe and claw toe, compared with standards by Coughlin and Mann

	Hammer toe	Claw toe	C&M
Flexor-extensor-tendon transfer in a flexible deformity	55%	41%	X
Flexor-extensor-tendon transfer in a rigid deformity	1%	3%	
PIP arthroplasty in a rigid deformity	76%	61%	X
PIP arthrodesis in a rigid deformity	53%	49%	
Capsulotomy/soft tissue release of the MTP- joint if necessary	61%	46%	X
Proximal phalangectomy in a rigid deformity	9%	4%	
Amputation is an option in a severe deformity	21%	17%	X
Exclusively asked for claw toe surgery:			
Extensor-tendon-lengthening in a flexible deformity		22%	X
Extensor-tendon tenotomy in a flexible deformity		26%	
Excision of the distal metatarsal in a rigid deformity		4%	
Metatarsal osteotomy in a rigid deformity		12%	

Opinions (%) on the surgical treatment of mallet toe, compared with standards by C&M.

	Mallet toe	**C&M**
Flexor- tendon tenotomy in a flexible deformity	58%	X
DIP arthroplasty in a rigid deformity	30%	X
DIP arthrodesis in a rigid deformity	58%	
Amputation of the distal phalanx is an option in severe cases	3%	

C&M, Coughlin and Mann.

The applied postoperative treatment in the evaluated departments is listed in Table 3.

According to the surgeons, the average estimated patient satisfaction rate after operative correction of a hammer, claw, or mallet toe was 82%.

Seven percent (five of 76) of all respondents evaluated the postoperative outcome with a radiograph, 88% (67 of 76) used the patient's judgment and physical examination as outcome measures, and 7% (five of 76) also used questionnaires or standardized scoring systems.

Eighty-seven percent (66 of 76) of all responding departments stated that higher age does not influence outcome after operative correction of lesser toe deformities. Sixty-five percent (49 of 76) of all respondents stated that malunion and pseudarthrosis do not influence post-operative outcome.

Table 3: Opinions (%) on postoperative treatment of lesser toe deformities, compared with standards by Coughlin and Mann

Postoperative treatment		C&M
Several days of bed rest	7%	
Applied compression bandage	63%	X
Removal of K-wire after 4 weeks	46%	X
4 weeks partial weight bearing	12%	
4 weeks postoperative special shoe	42%	X
Period of plaster	3%	

C&M, Coughlin and Mann.

DISCUSSION

Lesser toe deformities are highly prevalent, and the conservative and operative treatment of these deformities is very common in general orthopaedic practice. Just as in the literature, the current survey confirmed a wide variation in definitions, concepts, and treatment strategies of lesser toe deformities among the Dutch orthopaedic departments. We believe that these results are representative, with the survey response (75%) limiting a substantial nonresponder bias.

Only half of all responding departments had a protocol or consensus in the treatment of lesser toe deformities. This also agrees with the lack of consensus found in the literature. In 1996, Harmonson et al.[8] published a literature review on operative procedures of lesser toe deformities. The results of their study were inconclusive, mainly because of a limited number of prospective and randomized studies found in the literature. They could not conclude which procedure was best for which deformity.

In the present study, various definitions for each deformity were found among the evaluated orthopaedic departments. In our opinion, a correct diagnosis of a deformity is obligatory to communicate about perioperative parameters.

Multiple variations of the definition of hammer toe and claw toe were found, agreeing in only 24% and 9% of the cases, respectively, with the definitions of Coughlin and Mann.[4] These percentages of agreement are extremely low. While 44% of the respondents included MTP joint extension in the definition of a hammer toe, only 44% cited MTP joint extension as a criterion for the definition of a claw toe. Surprisingly, the largest group of respondents (26%) described a hammer toe as MTP joint extension with PIP joint flexion and DIP joint extension. In addition, several respondents (30%) described a claw toe as PIP flexion with DIP flexion. Criteria for a mallet toe deformity were more uniform: most respondents (70%) described a mallet toe as a flexion deformity in the DIP joint, in accordance with Coughlin and Mann.[4]

In the conservative treatment of lesser toe deformities, most scientific papers recommend shoe modifications and orthoses.[4] Most respondents reported the same conservative options, including a high percentage who used special insoles. Surprisingly, 15% of the respondents did not apply any conservative options in their treatment of lesser toe deformities.

Although the importance of making a differentiation in the treatment of a flexible and rigid deformity is stressed in the literature,[4] 12% of the respondents did not make this distinction. The literature also shows that it is important to distinguish between a hammer toe and claw toe, because these are different deformities with specific indications for surgery.[4] The MTP joint should be the distinguishing factor. However, in the current study 20% of the respondents stated that they did not discriminate between the treatment of a hammer toe or claw toe deformity.

As far as the operative treatment of a flexible toe deformity is concerned, 55% of the respondents regularly performed a flexor-tendon transfer in the treatment of a flexible hammer toe and 41% percent used this procedure for the treatment of a flexible claw toe. This is in accordance with what is generally advised in literature.[4,5] To a lesser extent, 26% and 22% of the respondents performed an extensor tenotomy or lengthening, respectively, in a flexible claw toe deformity.

Arthrodesis of the PIP joint of a lesser digit was first described by Soule[14] in securing an arthroplasty.[14] This has been the most-often cited procedure for lesser toe deformities in the literature, usually with temporary Kirschner wire fixation.[15] Most of the respondents (92%) in our study used a Kirschner wire for securing a PIP joint arthrodesis or arthroplasty, which was often removed after about 3 to 4 weeks.

The literature does not conclude which operative procedure for treatment of rigid lesser toe deformities has the best outcome. Most respondents in the present study regarded PIP joint resection arthroplasty as the gold standard for rigid hammer toe and claw toe, hence this should be interpreted as the relative gold standard in the Netherlands. As 76% of our respondents reported the use of a PIP joint resection arthroplasty and 53% the use of a PIP joint arthrodesis in the treatment of a rigid hammer toe, it can be concluded that both methods are popular and are used to correct the same type of deformity by the same department. The same is true for rigid claw toes. Coughlin and Mann[4] described PIP joint resection arthroplasty with Kirschner wire fixation as their standard procedure for these rigid deformities.[4]

In the current study, respondents showed that DIP joint arthrodesis (58%) was used more often than DIP joint arthroplasty (30%) for a rigid mallet toe deformity. Flexor-tendon tenotomy was used in 58% of all responding departments and amputation in only 3%. Minimal research on mallet toes can be found in the literature. Coughlin and Mann[4] suggested bony decompression of the DIP joint, with resection of the head of the middle phalanx and Kirschner wire fixation, and release of the flexor digitorum longus tendon as an operative procedure for a fixed mallet toe.[4]

Femino and Mueller[7] showed that there are many factors that influence outcome and complication rate after lesser toe surgery. Most respondents in the current study stated that age did not influence outcome after operative treatment of lesser toe deformities. Newman and Fitton[12] showed that fusion was not required for a successful result when attempting arthrodesis. This was supported by most of our respondents (65%).

Discussion regarding the differences in approaches towards hammer toe and claw toe actually is useless because the definitions used do not coincide. Thus, a deformity described as a severe claw toe by one department would be described as a severe hammer toe by another. Many claw toes were incorrectly defined as hammer toes and treated as such, and vice versa. This might explain why, in a hammer toe, up to 60% of all respondents included an MTP joint capsulotomy in the operative treatment, while others, by definition, did not because they would call these deformities claw toes. This might also account for the 20% of respondents who made no discrimination in the treatment between a hammer toe and claw toe. Therefore, we chose to put the results of the operative treatment of both hammer toe and claw toe together in Table 2. The confusion in definitions reflects that the treatment patterns for hammer toe and claw toe are almost identical for both deformities. This suggests that in common practice more than the reported 20% of surgeons do not discriminate between the treatment of hammer and claw toes. Particularly, the higher incidence of MTP joint release in hammer toes is suggestive.

The reactions to the questionnaire showed that there are different ideas and concepts about the pathophysiology of hammer toe and claw toe deformities. Forty-four percent of the respondents included MTP joint extension as a criterion for the definition of a hammer toe, whereas 56% did not describe MTP joint extension as part of the definition of a claw toe. Imbalance of the intrinsic muscles is the underlying mechanism that causes these deformities. Our hypothesis is that these deformities are different stages of the same pathophysiological process. In our opinion, MTP joint extension should be the discriminating factor between a claw toe and hammer toe deformity. This difference of opinion may have important clinical consequences, as an indication for surgery depends on the correct diagnosis.

In accordance with Coughlin and Mann, most respondents applied a pressure bandage in the postoperative treatment of lesser toe deformities. About half of all respondents used a special postoperative shoe.

Although most Dutch orthopaedic surgeons seem to follow their 'own' treatment strategies, they estimate a high patient satisfaction rate (82%). If true, this is in accordance with percentages found in the literature.[1,8] This is similar to the situation regarding hallux valgus: a multitude of different procedures can be used, all producing quite good results. However, recognizing that a variety of different types of hallux valgus exists, a consensus has been suggested to apply optimal procedures for each different type of deformity and to introduce uniform scientific communication.[10]

In conclusion, the use of a clear description and distinction between different types of lesser toe deformities is lacking in Dutch orthopaedic practices, and (consequently) there is no consensus regarding the treatment strategies of these deformities. Only if a consensus on definitions of the different lesser toe deformities is reached and applied can treatment results be correctly interpreted and improved.

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Chapter 3

Definitions of Hammer Toe and Claw Toe: an evaluation of the literature.

J Am Podiatr Med Assoc. 2009 May-Jun;99(3):194-7. Review.

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ABSTRACT

Background: Lesser toe surgery is among the most conducted interventions in general orthopedic practice. However, the definitions of hammer toe and claw toe are not uniform. The objective of this literature study is to propose clear definitions for these deformities to establish unambiguous communication.

Methods: A literature search was performed in the PubMed database (May 2006). Of 81 eligible articles, 42 that stated a clear definition of hammer toe or claw toe were selected.

Results: In all 35 articles in which hammer toe was clearly defined, flexion in the proximal interphalangeal joint was part of the definition. Seventeen articles (49%) defined hammer toe as a combination of metatarsophalangeal extension and proximal interphalangeal flexion. Thirteen articles showed flexion of the proximal interphalangeal joint as the single criterion. Twenty-three articles with a clear definition of claw toe were selected. Twenty-one articles (91%) showed metatarsophalangeal extension as part of the claw toe deformity. Twelve articles (52%) regarded metatarsophalangeal extension and flexion of the proximal interphalangeal and distal interphalangeal joints as the essential characteristics. Seven articles described a claw toe as metatarsophalangeal extension with flexion in the proximal interphalangeal joint.

Conclusions: There are variations in the definitions of lesser toe deformities in the literature. We propose that extension of the metatarsophalangeal joint is the discriminating factor and essential characteristic for claw toe. Claw toe and hammer toe should be characterized by flexion in the proximal interphalangeal joint, which is the single criterion for a hammer toe. The flexibility of these joints could be a basic factor in discriminating between these deformities. The development of these deformities should be regarded as a continuum in the same pathophysiologic process. (J Am Podiatr Med Assoc 99(3): 194-197, 2009)

INTRODUCTION

The incidence of symptomatic claw toe and hammer toe in the literature ranges from 2% to 20%.[1] Surgery for these deformities is among the most commonly conducted interventions in general orthopedic practice.[2,3] There are many variations of the definitions of claw toe and hammer toe in the scientific literature, which is remarkable for such a common orthopedic problem. These terms are used interchangeably, and there seems to be a lack of uniformity.

We performed a literature search to identify variations in applied definitions of hammer toe and claw toe. The objective of this literature study is to propose clear definitions of claw toe and hammer toe. Only then can communications about these conditions be unambiguous. Uniformity in definitions of hammer toe and claw toe is mandatory in communications about indications for and interpretations of treatment of these abnormalities.

METHODS

An analysis of the literature was conducted in the PubMed database (May 2006) using the following keywords: *lesser toe deformities, hammer toe,* and *claw toe.* Articles that met the search parameters were analyzed. Articles with a clear definition of hammer toe or claw toe were included. We included relevant literature dating from 1950 until May 2006. In addition, references cited in these articles were screened for relevant information. We also analyzed accessible relevant orthopedic textbooks and foot and ankle textbooks that met the search parameters. Textbooks with clear descriptions of these deformities were included. We also consulted the Cochrane Database.

We reviewed 81 articles about lesser toe deformities. Forty-two articles stated a clear definition of claw toe or hammer toe.[1,2,4-43] Single citations of authors were used. In these cases, the most recent articles were included. For each described definition of hammer toe or claw toe, the positions of the metatarsophalangeal, proximal interphalangeal, and distal interphalangeal joints were recorded. Next, a subdivision into specific groups was made.

RESULTS

The variations in definitions are listed in Tables 1 and 2. Thirty-five articles that clearly defined hammer toe were reviewed.[2,4-7,9-15,17,19,21-23,25-40,42,43] All of the authors defined hammer toe as a deformity in which at least flexion of the proximal interphalangeal joint is present. Seventeen articles (49%) defined hammer toe as a combination of extension of the metatarsophalangeal joint and flexion of the proximal interphalangeal joint. Thirteen articles showed flexion of the proximal interphalangeal joint as the single criterion for hammer toe deformity.

Regarding claw toe deformity, 23 articles were selected.[1,2,4,6-8,12,14-16,18,20,21,23,24,27,30,31,34,39-41,43] Twenty-one articles (91%) described extension of the metatarsophalangeal joint as the primary characteristic of claw toe deformity. Twelve articles (52%) regarded extension of the metatarsophalangeal joint and flexion of the proximal interphalangeal and distal interphalangeal joints as the basic characteristics for claw toe deformity. Seven articles (30%) described claw toe as an extension of the metatarsophalangeal joint and flexion of the proximal interphalangeal joint.

Table 1. Articles with Specific Definitions

Hammer Toe	Claw Toe	MTP Joint		PIP Joint		DIP Joint	
(n = 35)	(n = 23)	Extension	Flexion	Extension	Flexion	Extension	Flexion
17	8	x			x		
1	12	x			x		x
2	0	x			x	x	
1		x			x		
2	0				x		x
0	1	x			x		
0	1						x
13	0				x		

Abbreviations: DIP, distal interphalangeal; MTP, metatarsophalangeal; PIP, proximal interphalangeal.

Table 2. Deformities per Joint per Article

		MTP Joint		PIP Joint		DIP Joint	
Deformity	No.	Extension	Flexion	Extension	Flexion	Extension	Flexion
Hammer toe	35	20	0	0	35	4	1
Claw toe	23	21	0	0	21	0	15

Abbreviations: DIP, distal interphalangeal; MTP, metatarsophalangeal; PIP, proximal interphalangeal.

DISCUSSION

Boyer[44] described an extensor tenotomy as the first procedure for the correction of hammer toe deformity in 1816. Many soft-tissue and osseus procedures for the correction of hammer toes and claw toes were introduced thereafter. Lesser toe deformities are highly prevalent, and the treatment of these deformities is common in general orthopedic practice. However, despite the long history of scientific publications and the frequency of these deformities, this study shows that there is no existing consensus regarding the definitions of claw toe and hammer toe. Diversity of opinions about the pathophysiologic process and lack of prospective research into this specific subject might, in our opinion, explain these variations. Also, differences in training might be an explanation.

Relevant randomized controlled trials are rare because of difficulties in creating uniform patient groups, limitations in grading different stages of the pathophysiologic process, and restricted reproducibility. The lack of important clinical problems, as a result of these deformities, can also explain the limited number of prospective studies. In practice, a multitude of different surgical procedures can be applied, all producing good results.

We did not have access to certain American podiatric medicine literature. We agree that this is one of the limitations of this study. We tried to compensate for this by extensive consideration of scientific articles. Based on the results of this review of the literature, most articles characterized hammer toe as metatarsophalangeal extension combined with a proximal interphalangeal flexion position and claw toe as metatarsophalangeal extension with flexion of the proximal interphalangeal and distal interphalangeal joints. This conclusion does not reflect the intention of this study. The rationale of this study was to investigate the uncertainties surrounding the definitions of hammer toe and claw toe and to provide an overview of the literature with applied definitions. The present study indicates the differences of opinion regarding the definition of, and, therefore, communication on, hammer toes and claw toes. A single definition should end this ambiguity.

The development of a toe deformity may be the result of different pathophysiologic processes. Claw toe as a result of chronic synovitis of the metatarsophalangeal joint is probably different from claw toe as a result of muscular imbalance.[14] The development of claw toe as a result of muscular imbalance in patients with diabetes is probably similar to the process in patients with other causes of peripheral motor polyneuropathy. The formation of hammer toe might very often precede the formation of claw toe. Within this presumably similar pathophysiologic process, it is difficult to make a distinction between these deformities. Differentiation is, then, a matter of staging the extent of the deformity.

In the literature, we found no general classification to standardize the extent of the deformity. There is no strict difference between physiologic and pathologic deviation of the lesser toe joints. From this perspective, distinguishing between the spectra of the deformities is difficult. This explains that, in practice, a deformity described as claw toe by one physician can be described as hammer toe by another.

We suggest that the discrimination between hammer toe and claw toe be performed on the basis of the state of the metatarsophalangeal joint. This should also account for gradation of these deformities. This is in accordance with Coughlin and Mann,[14] as they define flexion of the proximal interphalangeal joint as the single criterion for hammer toe. In their opinion, claw toe is defined as a hammer toe deformity with extension into the metatarsophalangeal joint, suggesting a continuum of the pathophysiologic process. Discrimination, however, remains unclear as the degree of metatarsophalangeal extension is undefined. In addition, flexibility or rigidity, with its important clinical consequences, is not described.

We need to differentiate between hammer toe and claw toe by describing the position and flexibility of the proximal interphalangeal and metatarsophalangeal joints. A fixed flexion deformity at the proximal interphalangeal joint could be defined as hammer toe as long as the metatarsophalangeal joint is flexible. However, claw toe could be defined as an extension contracture in the metatarsophalangeal joint with a decline in function.

It is known that an extension contracture in the metatarsophalangeal joint often results in pain and increased plantar pressure under the metatarsal head.[11,45,46] Bus et al[11] showed that the toe angle (a measure of deformity) had a positive correlation with plantar pressure. Displacement of the plantar fat pad plays an important role. Only if a consensus on definitions of the different lesser toe deformities is reached and applied can treatment results be correctly interpreted and improved.

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Chapter 4

Lesser Toe PIP Joint Resection Versus PIP Joint Fusion: a Randomized Clinical Trial.

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ABSTRACT

Background: It is unclear whether proximal interphalangeal joint (PIPJ) resection or fusion leads to superior clinical outcome in patients undergoing hammertoe surgery. The purpose of this study was to prospectively evaluate a series of patients undergoing this surgery.

Methods: Patients with one or more toes with rigid PIP flexion deformity were prospectively enrolled. These patients were randomly assigned to undergo either PIPJ resection or PIPJ fusion. In addition to the PIPJ procedure, a metatarsophalangeal joint (MTPJ) release was performed if deemed necessary. Follow-up was up to 1 year postoperatively. Twenty-six patients (39 toes) were included in the PIPJ resection group and 29 (50 toes) in the PIPJ fusion group.

Results: Thirty-four underwent an MTPJ release. No significant difference in foot outcome scores (American Orthopaedic Foot & Ankle Society scale, the Foot Function Index, and visual analog scale pain) could be detected after 1-year follow-up. A statistically significant difference was found regarding the toe alignment in the sagittal plane in favor of PIPJ fusion.

Conclusions: Our randomized controlled study did not show any clinical outcome difference between PIPJ fusion and PIPJ resection. Both procedures resulted in good to excellent outcome in pain and activity scores.

Level of Evidence: Level II, lesser quality RCT or prospective comparative study.

Keywords: forefoot disorders, hallux disorders, outcome studies, pip flexion deformity, treatment, fusion, resection

INTRODUCTION

The incidence of lesser toe deformities in the general population reported varies from 2% to 20%.[9,10] There is an ongoing debate regarding the definition of lesser toe deformities.[26,27] In the present study, a claw toe was defined as a flexion deformity of the proximal interphalangeal joint (PIPJ), with a hyperextension deformity of the metatarsophalangeal joint (MTPJ).[27] Operative procedures of lesser toes are among the most common operative interventions within general orthopedic practice.[13] Although various treatment options have been reported, usually the rigid PIPJ deformity is corrected through either resection or fusion.[4,8,11,14,17,29] These procedures do not differ much except for the resection of the proximal end of the middle phalanx. However, these procedures both have advantages and disadvantages. The MTPJ deformity is most commonly corrected through joint release, frequently with additional extensor tendon lengthening or tenotomy.[8,11,13,14,22]

Many different operative procedures of lesser toe deformities can be found in the literature. However, these lack methodological quality and comparative design with divergent outcomes.[14] Moreover, there is no international consensus on the operative treatment of lesser toe deformities. No previous randomized trials have been performed comparing 2 frequently performed interventions for PIPJ deformity, resection, and fusion. The goal of the present study was to compare the effectiveness of PIPJ resection with PIPJ fusion among a population with rigid PIP flexion deformity with a randomized prospective study.

METHODS

Study Population

Patients were prospectively enrolled in 3 institutions in the Netherlands and Belgium. These institutions consisted of the University Hospitals Leuven (B), Sint Maartenskliniek (NL), and Isala hospital (NL). Approval for this study was obtained from the local ethics committees and the patients were recruited after taking their written informed consent.

All patients had one or more rigid PIP flexion deformities with extension deformity of the MTPJ, resulting in metatarsalgia and, commonly, with painful callosities on the dorsal aspect of the toes. These deformities, with a flexion deformity of the PIPJ with hyperextension deformity (extension contracture) of the MTPJ, were defined as claw toes in the current study.[27] Hallux valgus was not an exclusion criterion. The other inclusion criteria were as follows: age between 18 and 85 years and mental competence. All subjects had undergone unsuccessful conservative treatment for a minimum of 6 months.

Patients were excluded in case of (1) previous ipsilateral forefoot surgery; (2) simultaneous operative intervention on the same foot during the same session other than forefoot surgery; (3) specific comorbidity (ie, arterial insufficiency, complex regional pain syndrome, diabetes mellitus, neuropathy, generalized joint disease, and/or an active infection); and (4) pre-existent impaired mobility which would hamper postoperative rehabilitation (eg, hemiplegia).

The patients were interviewed and examined by orthopedic surgeons at the outpatient clinic before their inclusion. The actual inclusion and follow-up visits, following a standard protocol, were performed by independent researchers.

Study Design

The current study had a prospective design with random allocation of eligible patients to undergo either PIPJ resection or fusion. The randomization was carried out according to an allocation concealment mechanism. One independent person sequentially assigned different subjects to the different interventions, by means of block randomization (10 subjects per block), using www.randomization.com. These data were recorded in nontransparent envelopes.[28] The allocation sequence was concealed to the participating physicians and researchers. Before the operative treatment, the surgeon received an envelope that was opened in the operating room that revealed the treatment.

Outcome

The clinical data collected were: demographic data, medical history, comorbidity and ASA classification.[2] Follow-up was at 2 weeks, 6 weeks, 3 months, and 1 year postoperatively. Two specific foot outcome measures were applied: the American Orthopaedic Foot & Ankle Society scale (AOFAS) and the Foot Function Index (FFI).[5,15,18] The Dutch version of the FFI was divided into a pain subscale (section B; consisting of 9 items) and an activity scale (section C; 9 items). Pain was assessed by a visual analog scale (VAS 0-10). Physical examination was performed focusing on details of the forefoot deformity, the alignment, the plantar fat pad, and mobility of the hallux and lesser MTP joints.

Standardized weight-bearing radiographs (anterior-posterior [AP] and sagittal plane) were obtained preoperatively, after 6 weeks and 1 year postoperatively. These were evaluated using the method of Sung et al, also evaluating (non) union of the PIPJ.[29] The alignment (AP and sagittal) of the PIPJ of the operated ray was measured. If several rays were operated on, only the second ray was measured. On the AP view, the angle was defined as positive if the deviation of the ray was lateral to the axis of the metatarsal, and negative if the deviation was medial. Because of overprojection, the alignment of the MTPJ could not be measured. All measurements were performed by the same author.

Operative Techniques

The operative procedures were discussed and practiced in detail during a cadaveric session, aiming at reduction of performance bias throughout the course of the study. If an operated toe in the present study exhibited an extension contracture at the MTPJ, an MTPJ release was performed in addition to the PIPJ procedure. All procedures were performed in accordance with the methods described by Louwerens et al.[21]

PIPJ resection. A dorsal longitudinal incision was used and the extensor tendon and joint capsule was also divided. Hohman retractors were shifted over the bone under the tendon and positioned around the phalanx just proximal to the joint on both sides. The head of the basal phalanx was resected, using either a bone cutter or an oscillating saw. Usually the resection height of this condylectomy was about 6 to 10 mm. The foot was positioned in simulated "standing position," and if tension and persistent malalignment were present, more bone could be resected. It was also determined if the basal phalanx was well aligned at the level of the MTPJ, without extension due to extension contracture of the MTPJ and/or contracture of the extensor tendon(s). In case of contracture, a dorsal capsulotomy of the MTPJ and extensor tendon lengthening were performed. If persistent subluxation occurred, a plantar release was conducted, using a McGlamry rasp. If necessary because of contracture of the flexor tendons, a flexor tenotomy was performed. A 1.0- to 1.25-mm K-wire was drilled through the center of the articular surface of the middle phalanx retrograde through this phalanx and the distal phalanx, holding the DIP joint in neutral position, exiting centrally at the apex of the toe. Hereafter, the K-wire was drilled forwards through the proximal phalanx as centrally as possible. With the foot in standing position and the MTPJ held in neutral position (slight extension, equal angle as the adjacent normal MTP joints), the K-wire was drilled across the MTPJ into the metatarsal bone.

PIPJ fusion. The approach was identical to that of the PIPJ resection. In general, less bone was removed from the distal part of the basal phalanx. The articular surface of the middle phalanx was also resected. Preferably, the cut surfaces on both sides were made at the level of metaphyseal cancellous bone with its optimal bone healing properties. The amount of bone resected depended on the amount of deformity. The more deformity, the more bone needed to be removed in order to obtain realignment. In case of contracture, a dorsal capsulotomy of the MTPJ and extensor tendon lengthening were performed. If persistent subluxation occurred, a plantar release was conducted, using a McGlamry rasp. If necessary because of contracture of the flexor tendons, a flexor tenotomy was performed. The technique of K-wire fixation started as described for PIPJ resection; however, at the moment the wire was drilled into the basal phalanx, the cut surfaces were compressed to ensure good bony contact.

Postoperative treatment. A dressing was applied for 2 weeks. Starting postoperatively, patients were permitted to fully weight bear on a forefoot-relieving shoe for a duration of 6 weeks. After 2 weeks, the stitches were removed. The K-wires were removed after 4 to 6 weeks. At that time, the patients received instructions on how to mobilize and exercise the MTPJ. Subsequently, the patients were permitted to fully weight bear on their own shoes.

Statistics

A 2-way analysis of variance (ANOVA), with between-factor surgery (fusion or resection) and within-factor measurement time (preoperative and 3 and 12 months postoperative), was used to indicate differences in outcome factors AOFAS, FFI B, FFI C, and VAS pain. The primary end point was defined as the AOFAS score after 1 year of follow-up. When a significant main measurement factor was found, a Bonferroni post hoc test was used to indicate which measurement times were significantly different.

Because a large number of subjects underwent an additional hallux valgus correction, a second statistical analysis was performed to indicate the effect of the hallux valgus correction. For this, a 3-way ANOVA was performed, with between-factors surgery (fusion or resection) and hallux (correction or no correction) and within-factor measurement time (preoperative and 3 and 12 months postoperative).

Concerning the radiologic outcome parameters, a 2-way ANOVA with between-factor surgery (fusion or resection) and within-factor measurement time (preoperative and 3 and 12 months postoperative) was used. The level of significance was set at $P < .05$

RESULTS

Twenty-six persons (39 toes) were included in the PIPJ resection group and 29 (50 toes) in the PIPJ fusion group (period of enrollment from 2008 until 2013). Thirty-four patients underwent an MTPJ release; 19 of these were among the PIPJ resection group. In the complete population, 53 second rays were operated on. In all patients, the second ray was corrected with or without additional rays, except for 2 persons who underwent correction of a third and fourth ray. We decided to include these 2 patients in the statistical analysis because these followed the same research protocol and were of additional value to the number of included patients. Additional 2-way ANOVA did not indicate that exclusion of these 2 patients would influence the outcome. The details of the study population per surgery group are shown in Table 1. There were no significant differences between the 2 groups for all subject characteristics, except for weight. There were complete data of 47 patients after 3 months and 51 patients after 1-year follow-up. There was no significant difference in numbers of first-ray surgery, between groups.

Figure 1 shows the mean and standard deviation of the outcome factors for both groups at preoperation and 3 and 12 months postoperation. The 2-way ANOVA revealed a main effect for measurement time for all outcome parameters ($P < .0001$). A significant improvement in all outcome scores between preoperation and 3 months postoperation and between preoperation and 12 months postoperation for both groups was found. The outcome scores between 3 and 12 months postoperation were not significantly different. With the numbers available, no main effect between groups could be detected (AOFAS $P = .46$, FFI B $P = .25$, FFI C $P = .90$, VAS pain $P = .71$). Additionally, no interaction effects could be demonstrated (P values were >.42).

Table 1. Demographic Data.

	Total	PIPJ Resection	PIPJ Fusion	
n	55	26	29	*P* Value
Gender (male/female)	12/43	6/20	6/23	.83
Age (y), M (SD)	62 (9)	61 (9)	63 (9)	.50
Height (cm), M (SD)	170 (10)	172 (11)	169 (11)	.31
Weight (kg), M (SD)	80 (15)	86 (12)	75 (12)	.004
Side (left/right)	25/30	12/14	13/16	.80
ASA classification (1), (I/II/III)	22/28/5	8/16/2	14/12/3	.33

Abbreviations: ASA, American Society of Anesthesiologists; M, mean; PIPJ, proximal interphalangeal joint; SD, standard deviation.

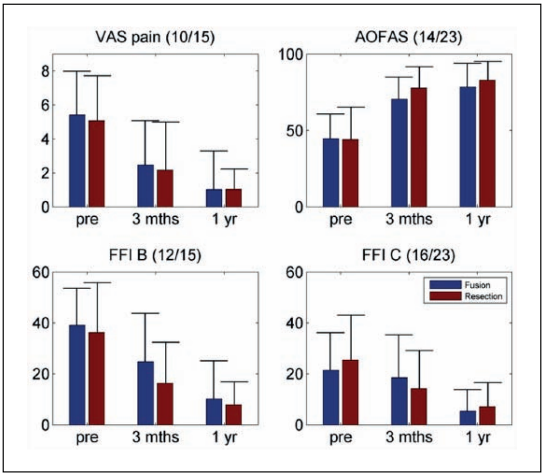

Figure 1. The course of the different outcome scores within time and comparison between the 2 groups. In parentheses is the number of patients per group (resection/fusion) with complete follow-up data per specific outcome score.

In the second statistical analysis, the effect of the first ray correction was evaluated, by adding first ray or no first ray correction as an extra factor (3-way ANOVA). Figure 2 shows the mean and standard deviation of the various outcome scores during the study, for the different groups. The 3-way ANOVA revealed a significant main effect of hallux (correction or no correction) for FFI B (P = .046) but no significance for FFI C (P = .056). No main effect could be demonstrated for AOFAS (P = .74) and VAS pain (P = .42). The patients with a first ray correction had a higher FFI B and FFI C outcome score (3 and 12 months postoperation), compared to the patients without a first ray correction. However, this effect was equal between the 2 groups (PIPJ fusion and PIPJ resection), as indicated by the absence of significant interaction effects. The 3-way ANOVA revealed no interaction between the hallux and the other 2 main effects, intervention and measurement time. Additionally, the other statistical results of the 3-way ANOVA were comparable to the 2-way ANOVA: no significant main effect for intervention (PIPJ fusion or resection), no significant interaction effects, and a significant main effect for measurement time for all outcome parameters.

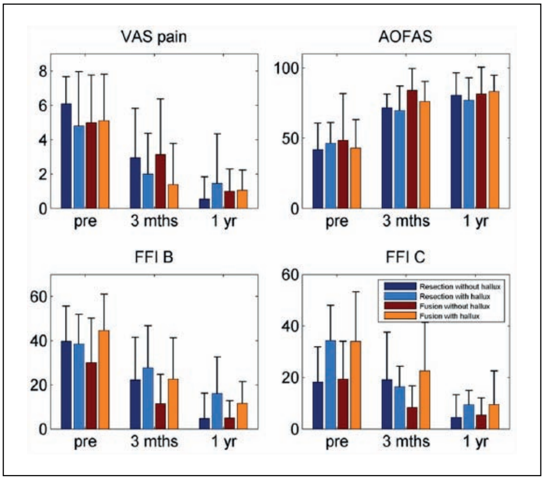

Figure 2. The course of the different outcome scores within time and comparison between the 2 groups, with influence of hallux correction or no hallux correction.

Complications

A total of 30 complications in 55 patients were reported. Three patients developed 2 complications. Twelve complications occurred within the PIPJ resection group of 26 persons. Eighteen occurred within the PIPJ fusion group, consisting of 29 persons. There was no significant difference in the number of complications between the 2 groups ($P = .38$). Eleven K-wire–related problems were reported, of which 9 occurred in one institution ($P = .019$ in comparison with the 2 other institutions). From this group, 2 patients underwent a reintervention for removal of part of the K-wire (defined as “K-wire” related complication). In another patient, a reintervention was performed to correct a residual toe malalignment (defined as “malalignment”). There were 6 floating toes (4 in resection group), 1 infection, 6 patients with toe malalignment (4 in resection group), 1 recurrence, 1 patient with symptomatic PIPJ pseudarthrosis, 2 patients with a sensory deficit, and 1 patient with superficial skin necrosis with spontaneous recovery.

Radiologic Outcome

The radiologic outcome parameter alignment of the measured PIPJ for the 2 groups are shown in Table 2, according to the method described by Sung et al.[29] It displays the preoperative comparison of radiologic alignment of the PIPJ in degrees, between the PIPJ resection and fusion group, in the sagittal and AP plane. Subsequently, the postoperative alignment between the 2 groups is displayed. In all patients (except for 2; surgery of third and fourth ray), at least the second ray was operated on; consequently, in these patients the second ray was measured. In case of the other 2 patients, the affected ray was measured. The 2-way ANOVA for the PIPJ alignment in sagittal view revealed a main effect for surgery ($P = .02$) and measurement time ($P < .001$) and no interaction effect ($P = .07$). PIPJ fusion resulted in a better alignment on the sagittal view, compared to PIPJ resection. Regarding the second PIPJ alignment in an AP view, no significant effects were found (surgery: $P = .17$; measurement time: $P = .09$; interaction: $P = .38$). There were 7 radiographic nonunions in 29 patients who underwent fusion. One was symptomatic (as described in the Complications section). The 39 toes with intended pseudarthrosis after PIPJ resection had comparable outcome to the 50 toes after fusion. MTPJ release did not influence postoperative sagittal alignment of the PIPJ ($P = .17$ postoperative sagittal alignment between MTPJ release and no MTPJ release).

Table 2. Pre- and Postoperative Radiologic Toe Alignment.

	Preoperation		1 Year Postoperation	
Alignment of PIPJ of Measured Toe	PIPJ Resection (degrees)	PIPJ Fusion (degrees)	PIPJ Resection (degrees)	PIPJ Fusion (degrees)
Sagittal (n = 47), M (SD)	63 (20)	60 (16)	30 (15)	15 (15)
Anteroposterior (n = 51), M (SD)	3 (12)	−2 (13)	4 (11)	2 (8)

Abbreviations: M, mean; SD, standard deviation.

DISCUSSION

In the current randomized controlled trial, no difference in clinical outcome between PIPJ resection and PIPJ fusion in patients with rigid PIP flexion deformity was found. The only difference was a greater improvement of sagittal radiologic alignment in the PIPJ fusion group. Most studies with a retrospective design that have been published describe the outcomes of operative correction of lesser toe deformities.[19,23,29] To our knowledge, this is the first randomized trial on this subject, and therefore we have more validity than prior studies. The 3 surgeons followed the same treatment protocol, which was assessed by independent researchers. These could be regarded as the strengths of this study.

Sung et al retrospectively reported outcome after 3 methods of hammertoe correction, including the Weil-Hammertoe-implant.[29] They found no difference between the PIPJ fusion and PIPJ resection arthroplasty group after an average follow-up of 54 months. After PIPJ fusion, their average VAS pain score was 1.9, and after PIPJ resection, 1.0; this result is comparable to the 1-year postoperative VAS scores after both procedures in the present study. The scores demonstrated slightly favorable axial alignment after PIP interpositional implant arthroplasty. A study by Lehman et al after PIPJ fusion defined a satisfied patient as one with an overall AOFAS score of 80 or higher.[20] Coughlin et al reported a mean AOFAS score of 83 after PIPJ fusion and Dhukaram et al a median AOFAS score of 83 after MTP release with PIPJ resection.[8,11] Our data showed similar AOFAS scores after different procedures. One year postoperatively, mean scores of 80.5 (SD = 15.9) after PIPJ fusion without hallux correction and 77.0 (SD = 15.9) after PIPJ fusion with hallux correction were measured. After PIPJ resection without first ray correction, the AOFAS score was 81.5 (SD = 19.1); PIPJ resection with hallux correction showed a 1-year postoperative AOFAS score of 83.3 (SD = 11.7). In the current study, both procedures, irrespective of first ray correction, resulted in satisfied patients with significant pain reduction and results comparable to those reported in literature.

We did find a statistically significant difference between the 2 groups regarding the toe alignment in the sagittal plane. PIPJ fusion resulted in better improvement of sagittal alignment. This could be interpreted as an important factor that could reduce problems over time, as deformity in this plane accounts for most symptoms. The sagittal alignment of the PIPJ was not influenced by MTPJ release. The accuracy of measurement of sagittal alignment yielded complexities in our study (overlapping from other rays), as similarly encountered in other studies.[12,29] This especially accounts for the MTPJ since no current consistent method exists for measuring MTPJ alignment on sagittal plane radiographs. Therefore, we did not include measurement of the MTPJ in our study. Sung et al did not find significant differences in sagittal alignment between PIPJ resection and fusion after an average follow-up of 53.8 months in a retrospective study.[29] Various studies evaluated different methods of stabilization of the PIPJ during operative correction of lesser toe deformities, which ultimately should lead to decreased risk of malalignment.[11,20] None of these detected a superior method.

A high complication rate with 30 complications in 55 patients was found in our study. The complication rate after surgery of lesser toe deformities reported ranges from 21% to 56%.[7,12,24,29] Our data showed a relatively high amount of radiologic non-union after PIPJ fusion, but the nonunion rarely resulted in pain. This painless non-union is in accordance with several other studies.[1,3,6,8,16] In the current study, the most prevalent complications were K-wire related, which occurred in 11 patients. This is comparable with the numbers for up to 18% of cases in the literature.[25] Most of the K-wire–related complications in our study occurred in the same institution. All perioperative details and treatment protocols were equal in all institutions. A possible explanation could be the drilling of a small-size K-wire across the MTPJ.

This study has several limitations. Although 3 centers were involved in the study, the number of patients who could eventually be included over 6 years was disappointing. The existence of PIP flexion deformity is related to all kinds of pathology, but the presence of such pathology was an exclusion criterion in many cases. Inclusion of patients with simultaneous first ray correction could be regarded as a deficiency of our study design. However, lesser toe deformities are often associated with first ray pathology. If the presence of hallux valgus would also have been an exclusion criterion, the period of inclusion would have even been longer. The number of first ray corrections was equally distributed between the 2 groups. The confounding effect of the first ray correction was tested with a 3-way ANOVA test and was not found to influence the results of either resection or fusion. However, patients with first ray correction showed higher FFI B and C scores. Hence, first ray correction resulted in worse FFI scores, without affecting the outcome of different PIPJ procedures. Another drawback of the present study was the missing follow-up data. We chose to only analyze those patients' data that were complete. Two- and 3-way repeated measures did not show any indication that inclusion of a higher number of patients would have led to a significant difference in the results. Finally, the short duration of postoperative followup was a limitation.

CONCLUSIONS

Our randomized controlled study did not show any clinical difference between PIPJ fusion and PIPJ resection in the treatment of rigid PIP flexion deformity. Both procedures resulted in good to excellent outcome in pain and activity scores. It remains disputable if better alignment in the sagittal plane would justify greater use of PIPJ fusion.

Declaration of Conflicting Interests

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Chapter 5

Rheumatoid forefoot deformity: pathophysiology, evaluation and operative treatment options.

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ABSTRACT

Despite recent advances in of pharmacological management rheumatoid arthritis, forefoot deformity, with its symptoms, remains a common problem, often requiring operative treatment. Typical deformities in these patients comprise hallux valgus and deformity of the lesser metatarsophalangeal (MTP) joints and toes. With regard to the lesser rays the standard operative procedure, advocated for the disabling forefoot pain in these patients, remains metatarsal head resection. It should be considered that with increasing success of pharmacological treatment the degree of forefoot deformity in these patients is becoming less and that resection of the lesser MTP joints is becoming more and more superfluous. This supports a trend towards metatarsal head-preserving surgery. The optimal treatment of the hallux deformity remains unclear. Fusion of the first MTP joint is, generally, recommended. This article will discuss the current surgical options in rheumatoid forefoot pathology.

Keywords Rheumatoid forefoot deformity . Preservation of metatarsal heads . Fusion of first metatarsophalangeal joint

INTRODUCTION

Although its worldwide incidence appears to be on the decline, rheumatoid arthritis continues to compromise the weight-bearing function of the foot [1]. It is an undisputed fact that the foot, and in particular the forefoot, takes a major place in the surgical treatment of inflammatory joint diseases. Pain as a result of synovitis of the metatarsophalangeal (MTP) joints is often the initial symptom of rheumatoid arthritis and it is reported that within the first three years of rheumatoid arthritis, approximately 65%of the patients have MTP joint involvement [2–4]. It is estimated that with chronic polyarthritis two thirds of patients will develop subluxation and dislocation of the lesser MTP joints. The incidence and severity of hallux valgus increases in the chronic stages (60–90 %). Eventually 5–22 % of these patients will be treated surgically [5, 6]. To date the extent to which the increased efficacy of the present pharmacotherapy results in a decrease of the prevalence of foot deformities in adults with chronic rheumatoid arthritis is unknown. Pharmacological therapy includes analgesics, anti-inflammatory agents, disease-modifying anti-rheumatic drugs (DMARDs) and biologicals [7].

As underlined by Karl Tillmann a thorough knowledge of the pathogenesis of these deformities and understanding of the biomechanical changes are necessary in order to plan effective surgical procedures (e.g. the selection of the best suited operative procedure among a number of methods at one's disposal) [8]. Continuous and simultaneous pharmacotherapy by the rheumatologist is imperative for both short-term and longterm results of treatment. This manuscript will discuss the current surgical options in rheumatoid forefoot pathology.

BIOMECHANICAL CHANGES OF THE FOREFOOT. WHY DOES IT HURT?

Deformities of the forefoot in patients with rheumatoid arthritis are characterised by the destruction of both the osseous and the soft tissue structures. It is generally accepted that synovitis is the initiating agent of destructive processes of the joint components. In the forefoot the MTP joints are most often involved. The synovitis, with ingrowth of pannus and cytokines, causes destruction of the joint cartilage and can lead to erosions of the metatarsal (MT) heads and the proximal phalanges of the toes. The severity of radiological changes is generally assessed by the Larsen classification, which correlates with the degree of articular destruction [9]. However, once the synovitis has been adequately treated with the help of pharmacotherapy or the acute symptoms have otherwise subsided it is not the amount of cartilage loss or subchondral bone resorption that determines the clinical symptoms, but the amount of resulting forefoot deformity. Thus eventually, as promulgated by Stainsby from a basic pathomechanical point of view, there is no difference between the situation of severe claw toe deformity in rheumatoid and non-rheumatoid patients [10].

Synovitis causes distension of the capsules and ligaments resulting in loss of integrity of the joint. Meanwhile erosions at the insertions of the ligaments may cause further slackening. The balance between intrinsic and extrinsic muscles is lost and eventually this may lead to subluxation, followed by dislocation of the MTP joints. At the first MTP joint this commonly results in hallux valgus. The proximal phalanges of the lesser toes are pulled dorsally and towards the fibular side. The fifth MTP joint commonly has a greater tendency towards a varus position. The continuous dorsal pulling on and extended position of the MTP joints, together with the pull of the flexor tendons of the toes, results in a clawing of the toes and eventually in fixed deformity of the MTP joints and the interphalangeal (IP) joints. Dorsal displacement of the long flexors and plantar intrinsics further enhance this process.

As a result of the dorsally extended position of the MTP joint the plantar plate is stretched dorsally and distally around the MT head (Fig. 1). The slips of the plantar aponeurosis which are attached to the plantar plate move dorsally. The MT head eventually can 'herniate' through the joint capsule and become tethered in a plantar position. The plantar fat pad and soft tissues intimately related to the aponeurosis are displaced distally to the MT head [11]. This results in loss of this specialised shock absorber on the plantar aspect of the MT heads. A thin inadequate layer of skin and subcutaneous tissue beneath the MT heads. The MT heads are now relatively more prominent and due to the increased biomechanical stress on the attenuated soft tissue, plantar callosities and/or large bursae can develop. This leads to metatarsalgia with impaired walking ability. For clinical purposes it is important to realise that a limited range of motion of the lesser MTP joints, in itself, might already cause metatarsalgia [12]. Clinical symptoms are most probably intimately related with the loss of cushion support provided by the plantar fat pad, and the more fixed and the more displaced the MTP joints are, the greater the incidence and severity of the metatarsalgia will be.

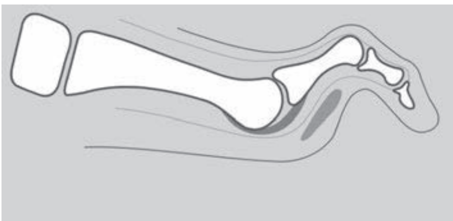


Figure. 1 Extension contracture in the MTP joint with distal dislocation of the plantar fat pad and displacement with adhesion of the plantar plate

Additional biomechanical factors subsequently play a role. The same forces applied by the tendons that lock the MTP joints in extension and the toes in flexion also result in a plantarward force on the MT heads (Fig. 2). This results in increased pressure on the soft tissues underneath the MT heads. Analogous to the increase of plantar pressure at the location of a plantar callosity as measured in diabetics, callosities in themselves probably also cause increased pressure in patients with rheumatoid arthritis. Seldom will this lead to ulceration of the plantar skin as most patients with rheumatoid arthritis do not suffer from serious sensory neuropathy.

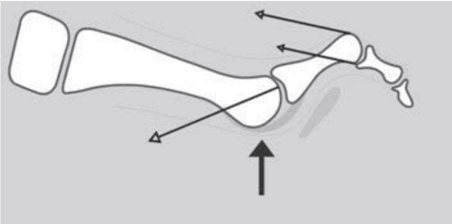


Fig. 2 Increase with weight-bearing of the plantar pressure on the MT head due to the pull of the extensor and flexor tendons in the case of claw toe deformity

A major additional factor that has so far not been discussed is the hallux valgus deformity that develops in the majority of patients with chronic rheumatoid arthritis. The process is similar to that taking place in the lesser joints. The proximal phalanx of the hallux is pulled laterally initiating hallux valgus. Once hallux valgus has developed a simple biomechanical model can explain that the deformity will probably progress. Force applied to the hallux through the flexor and extensor tendons, acting laterally, will pull the hallux in a further valgus position and the hallux also turns into pronation. The reaction force created by flexion and extension force pushes the first MT head in a medial direction resulting in an increased intermetatarsal angle and typical splayfoot. As a consequence the plantar load on the hallux diminishes with increase of the valgus angle. Furthermore, in a correctly aligned first ray dorsiflexion of the great toe causes an increase of the medial longitudinal arch of the foot with increase of pressure under the first MT head because of the windlass action of the plantar aponeurosis [13]. This mechanism plays an important role when weight is taken on the MT heads and is lost in the case of severe hallux valgus.

The loss of weight-bearing capacity of the first ray in patients with hallux valgus, occurring in the vast majority of chronic rheumatoids, is explained this way. It is essential to realise that this can result in synovitis of the adjacent second MTP joint resulting in subluxation and claw toe deformity and eventually even dislocation without any activity of rheumatoid arthritis. The overload of the second ray can cause stress fracture of the second MT bone and can, also, together with hypermobility of the first metatarsalcuneiform joint, result in arthritis and arthrosis of the second metatarsal-cuneiform joint. Thus, changes to the forefoot are associated with collapse of the midfoot and medial longitudinal arc. Vice versa, acquired planovalgus deformity is associated with the hallux valgus complex as outlined above. A severe valgus deformity of the foot is said to occur in ten to 30 % and lowering of the medial longitudinal arc in 50 % of patients with rheumatoid arthritis [14]. Clinically it is often unclear where the problems have started.

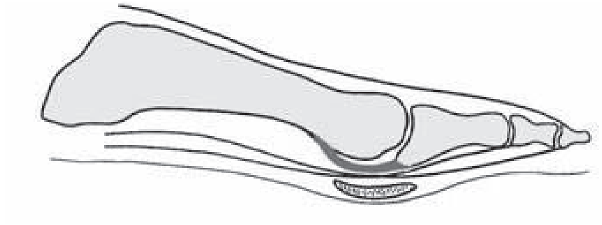
CLINICAL AND RADIOLOGICAL EXAMINATION

In the first place it is important to distinguish between pain due to the presence of active synovitis and pain as a result of post-arthritic changes. The most classic clinical picture, described as the pied douloureux des rhumatisants, will present all changes as described above: lowering of the medial arch, broadening of the forefoot, hallux valgus and clawing with dorsal (sub-)luxation of the toes. Patients might experience pain from various pressure points, often caused by the interaction of deformity and footwear: (1) at the site of the medial bunion, (2) between the hallux and the second toe, eventually the second toe might move over the hallux, (3) between fixed deformed lesser toes, (4) at the plantar aspect of the MT heads due to the changes described previously, (5) on the dorsal aspect of deformed toes and (6) at the lateral aspect of the fifth MT head, due to broadening of the forefoot, a bunion and bursa can develop. Subcutaneous rheumatoid nodules could also be the cause of pain (Fig. 3). These nodules are associated with a positive serum rheumatoid factor, often occurring at sites with some form of biomechanical overload, and are found in 20 % of patients. The changes as described must be differentiated from symptoms caused by active rheumatoid arthritis, other causes of synovitis such as Freiberg's disease, septic arthritis, Morton's neuroma, polyneuropathy and complex regional pain syndrome, etc.

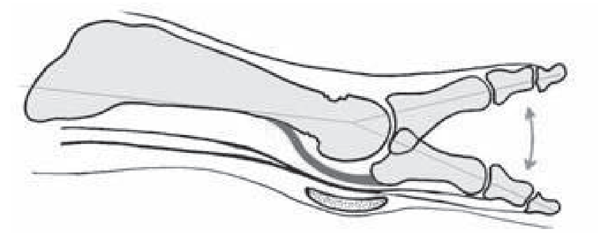
Figure 3. Claw toe deformity of the lesser rays and a rheumatoid nodule on the medioplantar aspect of the first MT head

In order to examine the forefoot systematically the range of motion of the MTP joints, the presence of subluxation or dislocation of the MTP joints, the presence of hallux valgus, the quality of the plantar fat pad, the presence of dislocation of the fat pad and the possibility to manoeuvre the fat pad back into place while plantarflexing the MTP joints as much as possible and applying some retrocapital pressure must be registered. In addition, the presence of hammer and/or claw toes and other possible causes of pressure points are examined. Weight-bearing anteroposterior (AP) and non-weight-bearing oblique radiographs of the forefoot are taken to establish the presence of erosive disorders which can be classified according to the Larsen classification, and the radiological hallux valgus parameters can be evaluated [9]. In Fig.4 a classification system is presented which can be used to grade the severity of the forefoot deformity [15].

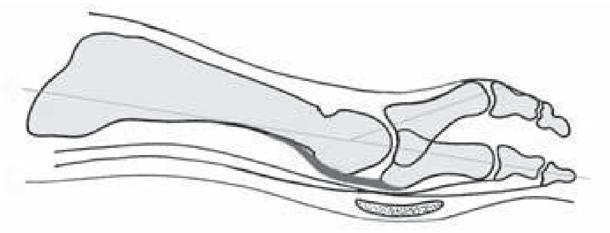
Fig. 4 The Nijmegen classification of forefoot disorders in patients with rheumatoid arthritis
Grade 0. No clinical changes in the MTP joints, no or mild radiographic changes (Larsen 0-1).



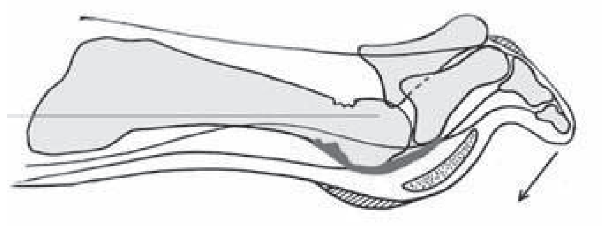
Grade 1. Decreased mobility of one or more of the joints, particularly of plantarflexion, with the ability to reduce the plantar soft tissues under the metatarsal heads, and with adequate quality of the plantar soft tissues and/or radiographic erosive changes (Larsen 2-5) or evident intra-articular changes.



Grade 2. Loss of plantar flexion in one or more of the MTP joints (up to 0_0), and loss of the ability to reduce the plantar soft tissues under the metatarsal heads, and/or with inadequate quality of the plantar soft tissues



A. with a hallux valgus of more than 20°
B. without a hallux valgus of more than 20°.
Grade 3. Extension contracture in one or more MTP joint, with or without radiographic subluxation or dislocation



A. with a hallux valgus of more than 20°.
B. without a hallux valgus of more than 20°.

MAKING DECISIONS

Changes to the forefoot, midfoot, hindfoot and leg are often related to one another and multiple joint problems can be involved at the same time. In order to make clinical decisions the problems concerning the foot and ankle must be evaluated as a whole and recommendations to the patients are individualised, depending on general health aspects, involvement of other joints, age, patient expectations, social aspects, and so forth. The choice of operative treatment depends on the amount of pain and disability and limitation of activity. The estimation of benefit of the operative procedure must be weighed against the results and possibilities of conservative treatment and against the risk of (post-)operative complications and the burden of post-operative recovery.

OPERATIVE TREATMENT

Several operative techniques in arthroplasty of the rheumatoid forefoot have been described. There are many names synonymous with forefoot operations (e.g. Kates, Hoffman and Clayton) [7]. They vary from type of incisions and procedure on the first MTP joint to the degree of resection of the lesser rays and the method of stabilisation. Each method has advantages and disadvantages. In general, scientific evidence regarding this subject is remarkably limited [7].

As in the operative treatment of hallux valgus it is best to be master of different techniques for the correction of different degrees and types of deformity. For instance, if only one or two of the lesser MTP joints with moderate deformity are involved, an operation preserving the MT heads may result in a better functional result than a resection arthroplasty, while resection arthroplasty is indicated in cases of severe deformity with loss of bone. Arthrodesis of the first MTP joint after a Keller resection arthroplasty might require a different technique than that for a primary arthrodesis. Individual patient-related factors including age, expectations, general health, medication, the other joints, previous surgery and skin quality should be taken into account. For one patient it can be most suitable to operate on both feet at the same operative procedure, while for another patient this might not be an option.

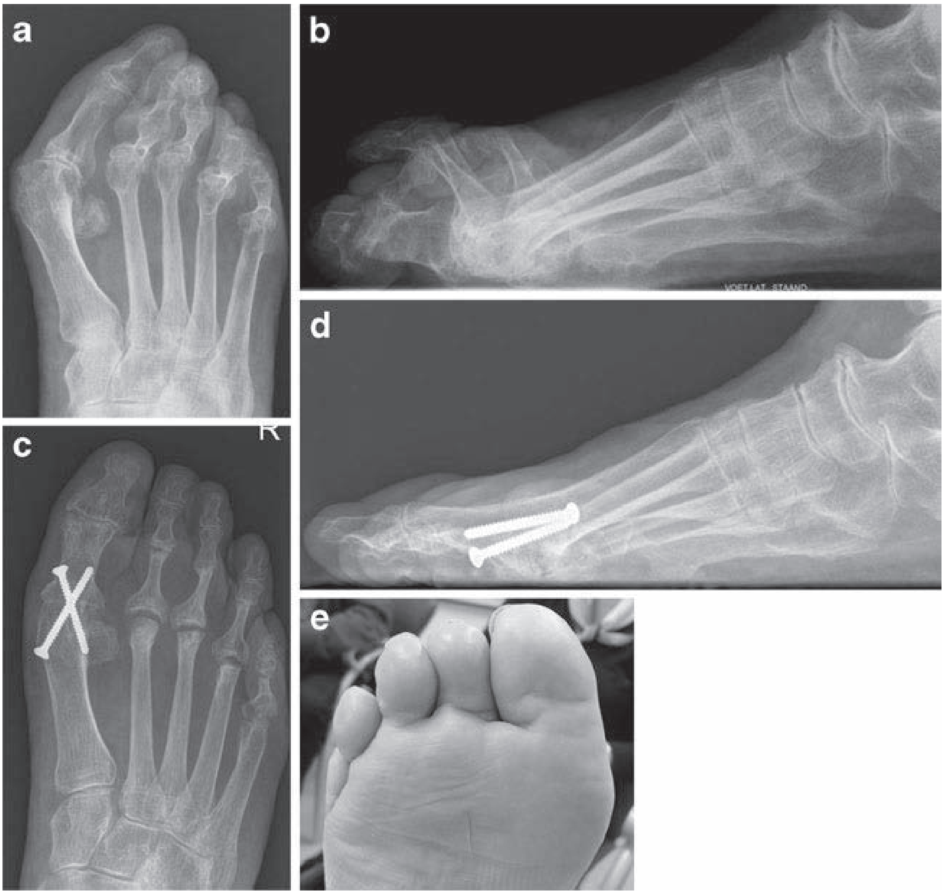
The aims of surgery are to relieve pain, correct deformity, to preserve or restore function and walking stability, increase footwear options and, while doing so, the cosmetic appearance may often be improved. The surgical options can be divided into operations for the hallux deformity and those for the lesser MTP joints.

THE LESSER RAYS

Resection of the MT heads

It is remarkable that the surgical procedure described by Hoffman in 1911 (for the correction of severe claw toe deformity!), by means of resection of all MT heads, continues to be the most advocated [16]. Fowler and Clayton have modified this procedure and have more or less initiated the present-day total approach to the rheumatoid forefoot deformity underlining the importance of adequate resection of bone, usually all MT heads, with realignment of the remaining weight-bearing ends of the metatarsals [17–20]. Generally, all the lesser MT heads are resected (Fig. 5) [5, 21–42].

Figure 5 ***a*** Preoperative AP view. ***b*** Lateral view illustrating severe extension contracture of the lesser MTP joints. ***c*** AP view 1 year after fusion of the first MTP joint and resection of lesser MT heads, tenotomy of the extensor tendons and PIP resections. ***d*** Lateral view illustrating good realignment. ***e*** Plantar aspect of the forefoot 1 year post-op with good clinical result



Excision of individual symptomatic heads leads to transfer metatarsalgia and thus to worse results than excision of all four and to more operations [19, 36, 43]. Others have concomitantly excised the base of the proximal phalanges [17, 18, 20–22, 31–33, 44–47]. Mann and Schakel found no difference in outcome comparing, retrospectively, a small series of patients in whom resection of the MT heads was combined with removal of the base of the proximal phalanges with a later group in whom only the MT head were resected [48]. However, the cosmetic appearance was more pleasing in the latter group. Complete resection of the proximal phalanges is reported to result in a high rate of recurrent deformity, weakened strength in the push-off phase of walking, less satisfaction and less relief of pain [32].

Several incisional approaches have been used, including a transverse or elliptical plantar incision and a dorsal transverse incision, but currently the use of multiple dorsal incisions is the most common [17, 18, 20, 21, 24, 30, 38, 45]. A plantar approach allows the removal of plantar calluses and bursae and offers easy access to the MT heads. Closing the skin after elliptical excision relocates adequate skin and the plantar fat pad beneath the MT shafts. Opponents of the plantar approach argue that there is no need to risk complications of the plantar incision, such as scar formation and delayed wound healing, since the plantar callosities resolve spontaneously once pressure is reduced and the patient can walk immediately after surgery [5, 48].

The goal is to realign the lesser MTP joints, most importantly in the sagittal plane in order to relocate the plantar plate and the plantar fat pad beneath the MTshafts. Ensuring that the toes are not pulled back into a claw toe position through lengthening, transfer or severing of the tendons and the use of K-wire fixation post-operatively contributes to maintaining this repositioning. The optimal amount of bone that should be resected remains debatable but depends on the magnitude of overlap of the proximal phalanx on the MT head and whether the extensor tendons are severed. Conservative resection, being the minimal amount of bone needed to decompress the joint, and threaded K-wires are associated with improved contact area, increased weight distribution through the lesser toes and improved clinical rating scores [34]. The MT bone should be cut in such a fashion that the plantar aspect of the distal stump is oriented parallel to the weight-bearing surface of the foot, to minimise the risk of a prominent surface. The length of the lesser metatarsals is related to the length of the second MT, with the third being slightly (two to three millimetres) shorter than the second MT and the fourth and the fifth metatarsals being progressively shorter in order to leave a smooth arc of resection (Fig. 5). Fixed toe deformities are corrected through IP joint resection, fusion or closed osteoclasis. Realignment of the small toes, decompression of length when needed and rebalancing of soft tissue, for instance through cutting or transposition of the flexor tendon(s) in the case of persistent clawing, probably contribute to an overall better result; however, little clinical evidence and no adequate quantitative information can be found in the literature.

Regardless of the precise technique used, the results of different methods of resection arthroplasty show a success rate of 70–90 % [21, 24, 27, 31, 39, 45]. The procedure is generally valuable for the patients with reported satisfaction rates up to 90% of the cases. It must be noted that these results are commonly not quantified. They particularly account for the short-term results and are due to the considerable amount of pain relief. After longer follow-up a variable rate (up to more than 50 %) of recurrent deformity with progressive deformity of the lesser toes, leading to metatarsalgia, recurrent plantar keratosis under the MT remnants and lateral deviation is reported [24, 27, 32, 34, 37–39, 42]. Pressure measurements show that the toes are very often defunctioned following MT head resection and the gait pattern in many of the patients shows heel strike and forefoot contact to be almost simultaneous [23, 28, 36]. The foot might be used more as a pedestal, rather than a lever and the rolling action can be absent. The reoperation rate is between ten and 15 %, the most common procedure being excision of a single plantar prominence. It is obvious that the results of resection arthroplasty of the lesser rays are influenced by the method that has been used for correction of the concomitant first ray pathology. Thus further discussion follows in a subsequent section.

Preservation of the MT heads

Synovectomy has been advocated in a small study, but considering the positive effect of present-day disease-modifying medication this no longer seems to be indicated as a stand-alone procedure [49]. This same improvement may influence renewed interest in techniques in which the MT heads are preserved (Fig. 6) [50, 51]. A technique which can be applied if only one or two of the lesser MTP joints are severely involved, in which all the MT heads are preserved, may result in a better functional result than a resection arthroplasty.

In techniques preserving the MT heads decompression in order to relocate the soft tissues is accomplished through tendon releases, resection of bone of the proximal phalanges, through shortening arthrodesis of the proximal interphalangeal (PIP) joints or by shortening the

Fig. 6 ***a*** AP view before surgery with dislocation of the MTP joints, but otherwise intact MT heads apart from the first MT. ***b*** Post-operative AP view, after fusion of the first MTP joint, lengthening of extensor tendons, dorsal release of lesser MTP joints, PIP resection, further complete release of the MTP joints also with a raspatory, anatomical reduction of the lesser MTP joints and 1.0-mm K-wire fixation. ***c*** AP view 1 year post-op showing good alignment

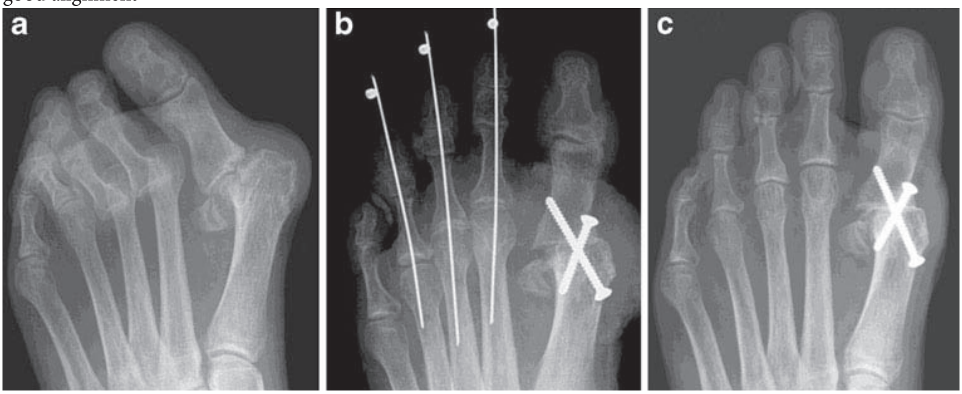


Figure 7. Use of McGlamry raspatory to release the plantar adhesions to the MT head

MT bones [35, 46, 51–64] (Fig. 7). By shortening the metatarsals the function of the plantar aponeurosis and the forefoot fat pad are not restored as advocated below [54]. Actually, some of the same disadvantages that exist for resection arthroplasty also apply for these osteotomy techniques, for instance the fact that all rays must be shortened includes those that are less or unaffected. To end up with a nicely aligned arc of the often osteoporotic and partially destroyed metatarsals is technically demanding. Toe stiffness after distal MT osteotomies frequently occurs and recurrent dislocation of the toe is reported in 15 % and transfer metatarsalgia in 11 % of patients.

The MT heads are important weight-bearing structures and at operation for resection often relatively healthy appearing MT heads are sacrificed unnecessarily [65]. By preserving the length of the MT bones and relocating the plantar plate and forefoot fat pad to their normal functional position, without dividing attachments to the deep transverse MT ligament and plantar aponeurosis, the weight-bearing function of the plantar aponeurosis and the deep transverse MT ligaments is maintained. Thus, the longitudinal windlass mechanism and toe function remain effective [11, 54, 55]. Using the method described by Briggs and Stainsby in a relatively small study, also including patients with other causes of claw toe deformity, good subjective and objective results with no obvious deterioration over time were found, after up to 11 years follow-up [54]. Dodd et al., in a study outside the originating centre, showed short-term outcome in 16 patients, with significant improvement in Manchester-Oxford Foot and Ankle score and satisfaction rate, following the Stainsby procedure [66]. van der Heide and Louwerens retrospectively reported good results of a repositioning technique in 54 feet, after a short-termfollow-up (mean 40 months, range 12–72 months) [67].

A retrospective study by Bhavikatti et al. describes a head-preserving surgical method, using Weil's shortening osteotomy and Scarf osteotomy [68]. They evaluated results in 66 procedures (49 patients). These procedures were performed in intermediate to severe stages of rheumatoid arthritis. Weil osteotomy was performed hypothetically reducing soft tissue tension by shortening of the metatarsal. After a mean follow-up of 51 months the mean American Orthopaedic Foot and Ankle Society (AOFAS) score improved from 39.8 preoperatively to 88.7 at final follow-up. Of the patients, 74 % reported their outcome as excellent and 13.5 % as good. Persistent pain was noted in 11 feet.

THE FIRST RAY

The first question that must be addressed concerns the issue of whether the hallux should be left alone when the disease is isolated to the lesser rays. An argument for routine excision of the first MTP joint is the risk that this joint will be affected by rheumatoid arthritis after time in any event [20, 69]. Nowadays pharmacotherapeutic treatment is very successful and the possibility that the first MTP joint remains uninvolved is much higher. Furthermore, the revision rate for no initial disease/no surgery to the first MTP joint has been reported to be no more than 14 % [34]. Findings in other studies support this number and it is advisable not to operate on a unaffected first ray [5, 39, 42]. However, it is sensible to tell patients that further painful deformity may develop, necessitating surgery [70]. So, a low threshold for inclusion of a symptomatic first ray may be recommended.

The second question concerns the mild to moderate hallux valgus deformity without arthritic changes of the first MTP joint. This time correction of the deformity is an integral part of the forefoot arthroplasty and the decision not to excise or fuse the joint in relation with the future possibility of arthritis and recurrence of hallux valgus is less easy. No sound information exists about the long-term results of osteotomy techniques and soft tissue procedures in patients with rheumatoid hallux valgus. Again, after advising the patients that the joint may become arthritic in the future and about the risk of recurrent deformity, in individual cases with a non-arthritic first MTP joint, it seems justified to correct a hallux valgus deformity using standard techniques in order to restore or maintain a normal function of the first MTP joint and the weight-bearing function of the first ray. Among these techniques a Lapidus fusion of the first metatarsal-cuneiform joint in combination with a soft tissue procedure of the first MTP joint in cases with unstable tarsometatarsal joint destruction should be considered [71]. For patients with a clearly diseased first MTP joint a choice must be made between fusion, resection or replacement through an implant of the first MTP joint.

Resection arthroplasty of the first MTP joint

In the past, certainly in Europe, the most commonly performed forefoot procedure was resection arthroplasty of all MTP joints [16–18, 20, 21, 23, 24, 26, 27, 32, 34, 36, 54]. Hamalainen and Raunio, alone, mention over 13,000 such forefoot arthroplasties [27]. The same authors and others report that after more than five years the percentage of satisfied patients (70–90 % at first) tends to decrease. The subjective long-term results remain quite good, but objective measurements show recurrence of hallux valgus, bony proliferation at the distal stumps of the metatarsals and callosities in 36–61 % of the patients [17, 18, 23, 24, 27, 32, 34, 38, 39, 45]. Recurrence of hallux deformity, found in more than 50 % of the cases in several large studies, is the major reason for reoperation and obviously plays a role in the development of problems in the lesser rays.

Two main types of resection arthroplasty are used. The first is excision of the entire MT head together with the sesamoids when fixed or part of it [16, 30]. Most often two thirds of the MT head is resected as described by Mayo [72]. The other is resection of the base of the proximal phalanx and of the medial prominence of the MT head or modification of the method first described by Keller [73]. Combinations have also been used. Comparing the Mayo and Keller procedures a significantly higher degree of forefoot pain, more frequent lesser toe deformities with lack of ground contact and a higher recurrence of hallux deformity with functional instability were found after Keller's procedure [24]. The success of a Keller procedure depends on the maintenance of alignment and better results are probably obtained by securing the sesamoids in their proper position under the MT head after a lateral release, performing a secure capsulorrhaphy and only resecting a limited portion of the base of the phalanx, thus not impairing the flexor function [74]. Using this method, however, more than one third of the joints become clinically stiff.

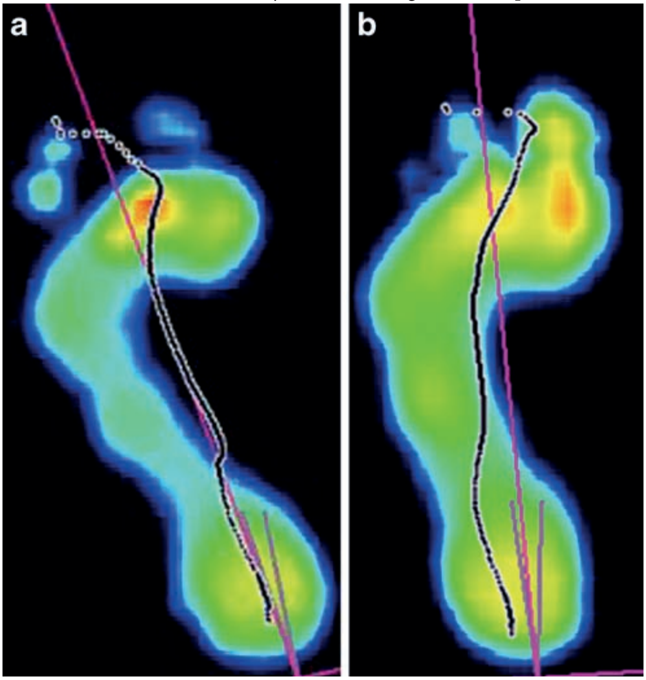
Fusion of the first MTP joint

Fusion of the first MTP joint in the correct position ensures a stable situation without risk of future deformity and is nowadays the generally advocated procedure in patients with rheumatoid arthritis. Studies, of limited methodological quality, advocating arthrodesis of the first MTP joint in combination with resection arthroplasty of the lesser rays have involved small numbers of patients and short follow-up periods [48, 75, 76]. Coughlin in a retrospective long-term follow-up study reports a 100 % fusion rate in 58 feet [5]. Subjective results were excellent and good in 30 of the 32 patients. The objective results were also favourable, only four feet being associated with limitation of daily activities and no special shoes were required. Reoperation was performed on 30 % of the feet, which is rather high. These included hardware removal, a procedure on the IP joint of the hallux, or additional procedures on the lesser toes or lesser MTP joints.

It has been argued thatwith a fused firstMTP joint, because of reduced movement possible in the first ray, the foot has a reduced contact time with the ground, thereby protecting the lesser MTP joints from dorsiflexion forces [76]. It is also postulated that after fusion the loading on the pulp of the big toe is increased, while the load transmitted through other parts is reduced (Fig. 8) [28].

The drawback of fusion is that it is technically more demanding. A non-union rate of 0–30 % has been reported [5, 26, 34, 48, 74]. Using modern techniques a union rate of more than 90 % must be achievable. A non-union is clinically not always painful [74]. A malunion in

Fig. 8 ***a*** Preoperative pressure measurement illustrating highest pressure centrally under the forefoot prior to surgery. ***b*** Same foot after fusion of the first MTP joint, illustrating transfer of pressure to the first ray



too much dorsiflexion or plantarflexed position is, however, poorly tolerated and may lead to revision surgery. The long-term risk of clinically relevant IP joint symptoms after arthrodesis seems to be acceptable.

Comparative studies

Studies have been performed comparing the results of fusion of the first MTP joint with those of resection arthroplasty, both in combination with resection of the lesser MTP joints including two randomised prospective trials [7, 26–28, 34, 39, 74, 77–79, 80–83]. Roughly, these studies show no significant difference in terms of clinical outcome, both methods providing significant pain relief. The short-term subjective results are slightly in favour of resection arthroplasty of the first MTP joint. However, these results, with lack of power, should be interpreted with care. The pedodynographic data collected in several of these studies are more in favour of arthrodesis, showing better load-bearing of the first ray and relative unloading of the central metatarsals [74].

The use of implants for the first MTP joint

To preserve mobility at the first MTP joint, a silicone prosthesis can be implanted. Mainly retrospective reports show encouraging results using a double-stemmed implant [33, 84].

However, high rates of osteophyte formation, osteolysis with bone cyst formation and implant failure may result from silicone particle-induced synovitis. Furthermore, the joint most often has reduced mobility, only.

One study retrospectively compared hinged silicone implant arthroplasty with resection arthroplasty of the first MTP joint [19]. Results showed trends in favour of resection arthroplasty.

Particulate synovitis may be prevented by adding titanium grommets between the bone and silicone [85]. The use of metallic hemi-implants may also solve this problem [86]. These complications and the risk of concomitant pain, recurrent deformity and metatarsalgia, together with the fact that most of us have no experience with this type of surgery, favour the use of other methods.

CONCLUSION

Despite recent advances in pharmacological management of rheumatoid arthritis, forefoot deformity, with its symptoms, remains a common problem, often requiring operative treatment. As a result of this improved treatment the degree of forefoot deformity is becoming less severe. In this perspective, we think the indication for resection of the lesser MTP joints is becoming less evident. However, this may support a trend towards MT head-preserving surgery.

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Chapter 6

Resection or preservation of the metatarsal heads in rheumatoid forefoot surgery? A randomised clinical trial.

Under review for publication in Foot and Ankle Surgery.

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ABSTRACT

Background

Despite impressive results of the pharmacological management of rheumatoid arthritis, still certain patients suffer from rheumatoid forefoot problems. Surgical treatment of these forefoot deformities can be an option. In literature no high-quality studies on this topic can be found.

The goal of present study is to compare the results of a metatarsal head (MTH) resecting technique with a MTH preserving technique in rheumatoid patients.

Patients and methods

Patients suffering from well-defined rheumatoid forefoot deformity were prospectively enrolled in three institutions. This non-blinded study had a randomised clinical design and eligible patients were randomly assigned to undergo either resection of preservation of the MTH. In all patients during the same session a first MTPJ arthrodesis was performed. The primary outcome measure consisted of the AOFAS score. The period of follow-up was one year.

Results

Fifteen patients were treated according to the method of MTH resection and 14 underwent MTH preservation. Three patients (two from the MTH resection group) withdrew from the study. Three other patients (MTH preservation) were excluded, as in these patients no first MTPJ arthrodesis was performed. Thus 23 patients (10 in MTH preservation group) were analysed.

After one year follow-up no significant differences in AOFAS score and additional outcome factors were found. A total of 10 complications in 23 patients were reported.

Interpretation

Current randomised clinical study did not show any clinical difference between MTH resecting and preserving procedures in patients suffering from rheumatoid forefoot deformity. Both procedures resulted in considerable improvement of pain and activity scores.

KEYWORDS: rheumatoid arthritis, forefoot, metatarsal head, surgery, preservation, resection

INTRODUCTION

Despite impressive results of the pharmacological management of rheumatoid arthritis (RA) progressive forefoot joint destruction still occurs in a subgroup of patients (Michelson et al. 1994, Matricali et al. 2006, van der Leeden et al. 2008, Jeng and Campbell. 2008, Otter et al. 2010, Hooper et al. 2012, Nikiphorou et al. 2014, Momohara et al. 2014). The standard operative procedure, advocated for the treatment of disabling forefoot pain in patients with rheumatoid forefoot deformity, remains to be resection arthroplasty with removal of the lesser metatarsal heads (MTH). Reports of MTH resecting techniques show a short term success rate of 70 to 90%, and this rate is particularly explained by pain relief (Vahvanen et al. 1980, Hamalainen and Raunio. 1997, Fuhrmann and Anders. 2001). Long term outcome is more variable, with recurrence of deformity, metatarsalgia and gait disorders (McGarvey and Johnson. 1988, Stockley et al. 1989, Hamalainen and Raunio. 1997, Tillmann. 1997, Mulcahy et al. 2003, Thomas et al. 2005).

From a biomechanical point of view strong arguments exist in favor of preserving the MTH. As described by Hicks the metatarsal heads are an essential component of the weight-bearing forefoot and ligamentous tie-bar systems (Hicks. 1954). It is very important to realize that the function of the toes is intimately related to the function of the plantar aponeurosis through the so-called well-known windlass mechanism, as proposed in detail by Hicks in the 1950s (Hicks. 1954). The main part of the aponeurosis becomes attached to the sesamoid bones, the deep transverse ligament of the foot sole and the fibrous sheaths of the flexor tendons, and hence the proximal phalanges. In the push-off phase, when the toes are dorsiflexed at the metatarsophalangeal joints, the plantar aponeurosis is tightened, thereby shortening the foot and increasing the longitudinal foot arch. Together with active contracture of muscles, the fascia, thus, enhances bracing of the foot for propulsion. MTH resection disturbs this mechanism.

The currently more effective pharmacological treatment reduces the severity of damage and deformity of the metatarsophalangeal (MTP) joints. From this perspective joint preserving techniques become more feasible and resection-arthroplasty seems to become less necessary. Even in the treatment of feet with severe RA forefoot deformity positive results have been published using surgical methods that preserve the metatarsal heads (Patsalis et al. 1996, Hanyu et al. 1997, Toolan and Hansen. 1998, Briggs and Stainsby. 2001, Barouk and Barouk. 2007, Nagashima et al. 2007, Niki et al. 2010, van der Heide and Louwerens. 2010, Roukis. 2010, Takakubo et al. 2010, Krause et al. 2011, Bhavikatti et al. 2012, Yano et al. 2013). Also, in several studies advantages in alignment and pain after MTH preserving procedures have been shown (Barouk and Barouk. 2007, Niki et al. 2010, Yano et al. 2013, Fukushi et al. 2015).

Stainsby et al. propagated a MTH preserving technique with resection of the proximal portion of the proximal phalanx (Briggs and Stainsby. 2001). This procedure might violate the windlass mechanism, as the plantar aponeurosis inserts at the base of the proximal phalanx.

In the technique we apply, shortening of the lesser ray is accomplished at the level of the proximal interphalangeal joint (PIPJ). The metatarsophalangeal joint (MTPJ), as a whole, remains preserved (van der Heide and Louwerens. 2010, Louwerens and Schrier. 2013).

While arguments exist in favor of MTH preserving surgery, the scientific evidence supporting this technique is sparse (Fukushi et al. 2015). The goal of the present randomised controlled study is to compare the clinical and radiological results of a metatarsal head (MTH) resecting technique with a MTH preserving technique in the treatment of patients with rheumatoid forefoot problems.

METHODS

Study population

Patients were prospectively enrolled in two institutions in The Netherlands (Sint Maartenskliniek, Nijmegen and the Isala Hospital, Zwolle) and one in Belgium (University Hospital Leuven). The local ethics committee obtained approval for this study (date of issue January 18 2008, NTR 1520). Patients were recruited after giving their written informed consent. The informed consent as the execution of the trial were in accordance with the Helsinki declaration.

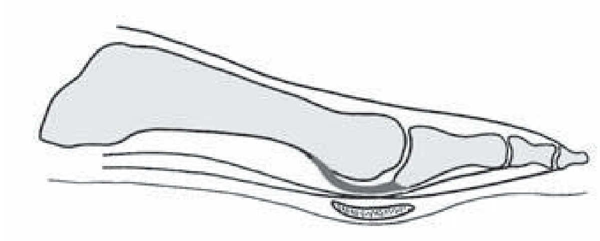
All patients suffered from an established erosive RA forefoot deformity resulting in metatarsalgia, due to MTPJ deformity, often including typical dorsal dislocation of these joints (MTPJ). The forefoot deformity consisted of grade 3 deformity of one or more of the lesser MTPJ, according to the Nijmegen classification [Figure 1] (Doorn et al. 2011, Louwerens and Schrier. 2013). This implies the presence of erosive changes of the joints and extension contracture in one or more of the lesser MTPJ, with or without radiographic subluxation or dislocation. As a result the plantar soft tissues (including fat pad) of the contracted joints were dislocated distally.

The other inclusion criteria were: age between 18 and 85 years and mental competence. Finally, all subjects had unsuccessfully been treated with conservative measures for duration of minimally six months.

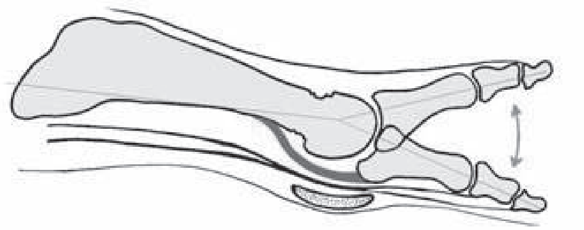
Patients were excluded in case of: (a) previous ipsilateral forefoot surgery; (b) active rheumatoid arthritis (synovitis of the MTPJ as cause of pain); (c) simultaneous surgical intervention on the same foot, during the same session, other than forefoot surgery; (d) specific comorbidity (i.e. arterial insufficiency, complex regional pain syndrome, diabetes mellitus, neuropathy and an active infection) and (e) pre- existent impaired mobility which would hamper postoperative rehabilitation (e.g. hemiplegia).

The patients were interviewed and examined by orthopaedic surgeons, at the outpatient clinic, prior to their inclusion. Independent assessors, who also collected all scientific data, performed the actual inclusion and follow up visits, following a standard protocol.

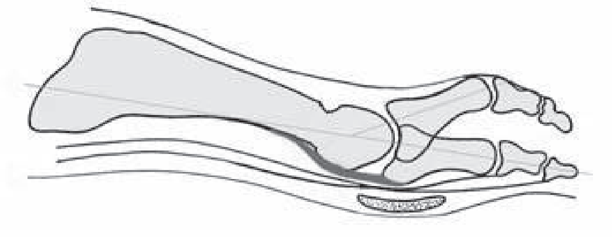
Figure 1. The Nijmegen classification of forefoot disorders in patients with rheumatoid arthritis.
a. Grade 0. No clinical changes in the MTP joints, no or mild radiographic changes (Larsen 0-1).



b. Grade 1. Decreased mobility of one or more of the joints, particularly of plantarflexion, with the ability to reduce the plantar soft tissues under the metatarsal heads, and with adequate quality of the plantar soft tissues and/or radiographic erosive changes (Larsen 2-5) or evident intra-articular changes.

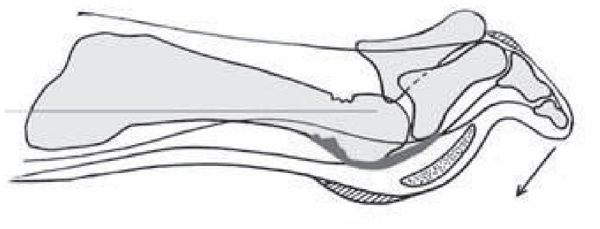


c. Grade 2. Loss of plantar flexion in one or more of the MTP joints (up to 0^0), and loss of the ability to reduce the plantar soft tissues under the metatarsal heads, and/or with inadequate quality of the plantar soft tissues.



A. with a hallux valgus of more than 20^0
B. without a hallux valgus of more than 20^0.

d. Grade 3. Extension contracture in one or more MTP joint, with or without radiographic subluxation or dislocation.



A. with a hallux valgus of more than 20^0.
B. without a hallux valgus of more than 20^0.

DESIGN OF THE STUDY

The current study had a randomised controlled design and eligible patients were randomly assigned to undergo either preservation or resection of the MTH. The randomisation was carried out according to an allocation concealment mechanism. One independent person sequentially assigned different subjects to the different interventions, by means of block randomisation (10 subjects per block), using www.randomization.com. These data were recorded in non- transparent envelopes (Schulz and Grimes. 2002). The allocation sequence was concealed to the participating physicians and researchers. Prior to the surgical intervention the surgeon received an envelope that was opened at the operating room and the included patient was assigned to the revealed treatment.

Clinical and radiographic outcome

The following clinical data were collected at base line: demographic data, medical history, comorbidity, ASA classification, RA disease duration and RA medication (Anon. 1963). Follow-up (FU) was at 3 months and 1 year postoperatively. Two specific foot outcome measures were applied: the American Orthopaedic Foot and Ankle Society scale (AOFAS) and the Foot Function Index (FFI) (Budiman-Mak et al. 1991, Kitaoka et al. 1994, Kuyvenhoven et al. 2002). The primary outcome measure was the AOFAS score. The AOFAS forefoot score has a maximum score of 100 points; the higher the score the better the condition. Two questions of the AOFAS scale, focussing on MTPJ function and functional limitations (item no. 2 and 4), were evaluated separately. The secondary outcome measures were: the FFI, the VAS pain score and the SF-36. The FFI is a Patient Reported Outcome Measure (PROM). The applied version of the FFI is divided in a pain subscale (section B; consisting of 9 items) and an activity scale (section C; 9 items). The higher the score on the FFI scale the worse the condition. Pain was assessed by a visual analogue scale (VAS 0-10) and general health was assessed by the SF-36, with application of the physical functioning (0-100) and pain (0-100) subscale (Ware and Sherbourne. 1992).

All patients were graded according to the Nijmegen classification, scoring the severity of the forefoot deformity [Figure 1] (Doorn et al. 2011, Louwerens and Schrier. 2013). This is a clinical classification system scoring MTPJ alignment and function, with evaluation of the position of the plantar fat pad. Standardized weight-bearing radiographs (anterior-posterior (AP) and sagittal plane) were obtained preoperatively and after one year postoperatively. The radiographs were used to evaluate the Larsen score, the alignment, positioning and congruency of the MTPJ and possible complications (Larsen. 1973). All clinical and outcome measurements were performed by independent well- instructed research nurses, limiting observer bias. One orthopaedic surgeon (J.S.) performed the radiographic assessment.

Operative techniques

The operative procedures were discussed and practised in details by the participating surgeons during a cadaveric session prior to the study, aiming at reduction of performance bias throughout the course of the study. All procedures were performed in accordance with the methods described by Louwerens and Schrier (Louwerens and Schrier. 2013).

Regardless of the surgical procedure performed on the lesser rays, patients underwent correction and stabilisation of the first ray through first MTPJ arthrodesis. Subsequently, one of the allocated interventions of the lesser rays was performed. Fusion of the first MTPJ was performed in appropriate dorsiflexion and with correct alignment (van Doeselaar et al. 2010). The method of osteosynthesis could differ per treating surgeon.

MT head resection

Each ray was separately approached through a dorso-linear incision, with exposure of the MTPJ and proximal interphalangeal joint (PIPJ). After lengthening or tenotomy of the extensor tendons a dorsal capsulotomy of the MTPJ was performed. Full release was often not achievable at this stage due to severe contracture and dislocation. Subsequently, a PIPJ resection arthroplasty was performed, in order to relieve the MTPJ through shortening. Hereafter further release of the MTPJ was performed. In case of dislocation of the MTPJ a systematic gradual release of the joints was done. The McGlamry raspatorium was used for final completion of the plantar release of the metatarsal heads [Figure 2]. In severe cases the flexor tendons, often dislocated to the dorsal aspect of the joint, were severed. Thereafter the metatarsal heads were resected. An oscillating saw was used to make cuts, starting on the dorsal aspect, proximal to the MT head, running plantar and proximally in an oblique fashion. Consequently the plantar aspect of the distal stump was oriented parallel to the weight-bearing surface of the foot. The length of the lesser metatarsals was related to the length of the second MT, with the third being slightly (two to three millimetres) shorter than the second MT, and so on [Figure 3]. Finally, the toes were realigned and stabilized by 1.00 to 1.25 mm K wires, which were positioned across the MTPJ into the metatarsal bones.

MT head preservation

This procedure was described in detail by Van der Heide and Louwerens (van der Heide and Louwerens. 2010). Each ray was separately approached through a dorso-linear incision. The procedure exposing and releasing the MTPJ and resecting the PIPJ was identical to the method of MT head preservation described above. The McGlamry raspatorium was used for final completion of the plantar release of the metatarsal heads [Figure 2]. Hereafter, full repositioning of the plantar soft tissues, including the fat pad, was possible. Finally, the toes were realigned and stabilized by 1.00 to 1.25 mm K wires, which were positioned across the MTPJ in the metatarsal bone [Figure 4].

Figure 2. Use of the McGlamry raspatory to release the plantar adhesions to the MT head (Louwerens and Schrier. 2013).

Figure 3. a. Preoperative AP view. b. Lateral view demonstrating severe extension contracture of the lesser MTPJ. c. AP view one year postoperatively, after first MTPJ fusion, resection of lesser MT heads, tenotomy of the extensor tendons and PIPJ resections. d. Lateral view illustrating good re-alignment. e. Plantar aspect of the forefoot one year postoperatively, with good clinical result (Louwerens and Schrier. 2013).

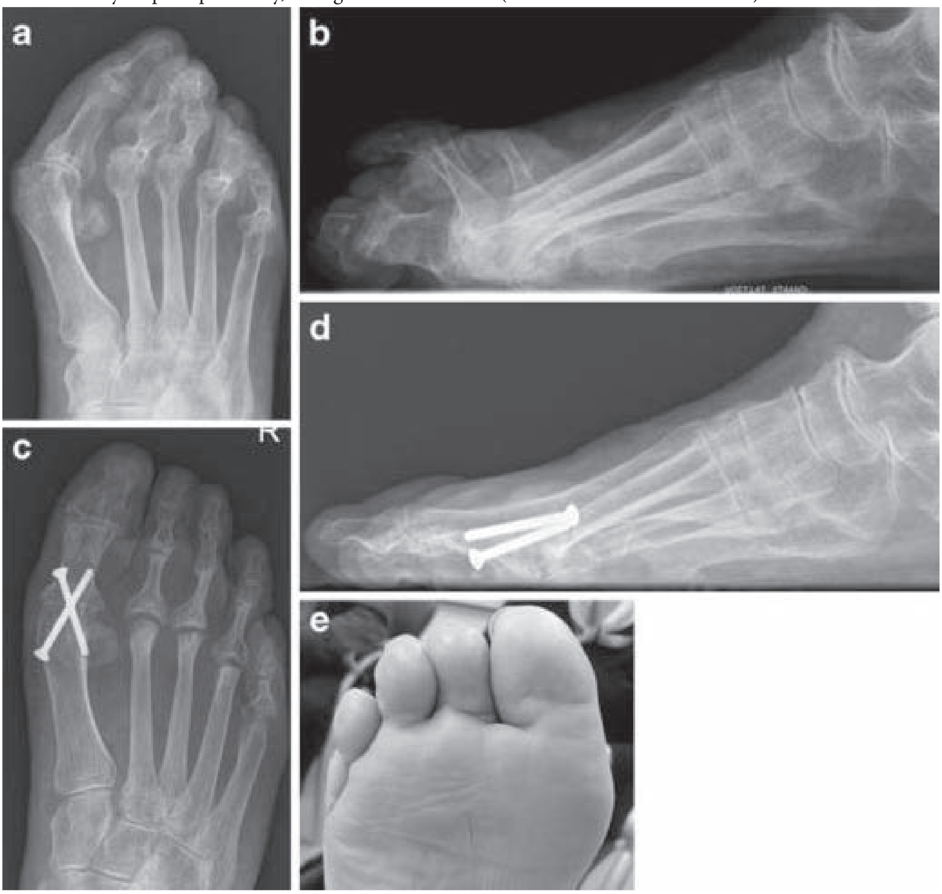
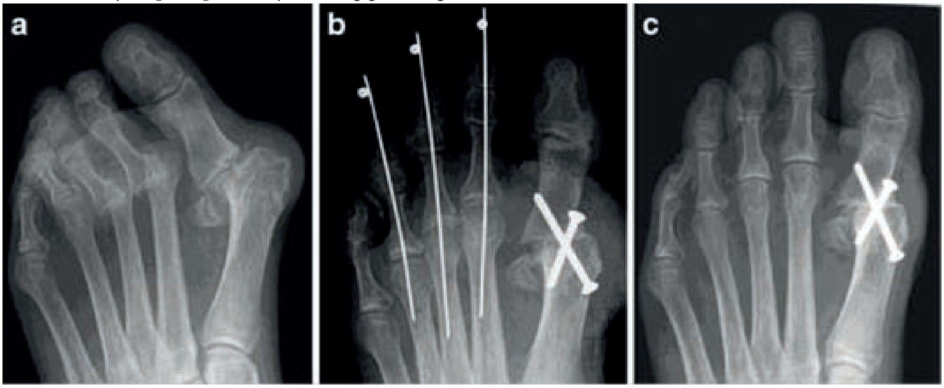


Figure 4. a. AP view before surgery, with dislocation of the MTPJ, but otherwise intact MT heads (except for the first MTPJ). b. Postoperative AP view, after first MTPJ fusion, lengthening of the extensor tendons, release of the lesser MTPJ, PIPJ resections, anatomical reduction of the lesser MTPJ and 1.25-mm K-wire fixation. c. AP view one year postoperatively showing good alignment (Louwerens and Schrier. 2013).



Postoperative treatment

After surgery, a dressing with little to no compression was applied, for the duration of two weeks. Starting postoperatively, patients were permitted to mobilise with a forefoot relieving shoe, for a duration of six weeks. After two weeks the stitches were removed. The K-wires were removed after 4 to 6 weeks. Subsequently, after union of the first MTPJ, the patients were permitted to fully weight bear on comfortable shoes. The patients were instructed how to move and mobilize the resected or reduced MTPJ.

Statistics

Student's *t*-test and the chi-square test were used to analyse baseline variables. A two way ANOVA, with between factor surgery (MTH resection or preservation) and within factor measurement time (preoperative, 3 and 12 months postoperative), was used to indicate differences in outcome factors AOFAS, FFI B, FFI C, VAS pain and SF-36. When a significant main measurement factor was found, a Bonferroni post hoc test was used to indicate which measurement times were significantly different. The level of assumed significance was set at $p<0.05$.

RESULTS

Clinical outcome

Twenty-nine patients with rheumatoid arthritis were enrolled in the study. Out of this group 15 patients were treated according to the method of MTH resection and 14 underwent MTH preservation. Three patients (two from the MTH resection group) withdrew from the study and did not complete the postoperative follow-up of one year. One of these patients had suffered a cerebral stroke eight months after the surgical intervention. The two other patients expressed to have motivational problems and, despite our encouragement to complete the study period, cancelled the appointment for the one year postoperative follow-up. Three other patients (MTH preservation) were excluded, as in these patients no first MTPJ fusion was performed. These six patients were not included in the statistical analysis [Table 1].

Table 1. Preoperative demographic data and baseline results.

	MT head resection [SD]	MT head preservation [SD]	*P* value
Demographic data			
N	13	10	
Gender (male/female)	2/11	1/9	0.70
Age (yrs)	65 (9)	63 (9)	0.67
Body weight (kgs)	69 (13)	73 (21)	0.56
Height (cms)	166 (8)	169 (9)	0.51
Baseline results			
ASA classification (I/II/III)	1 / 7 / 5	1 / 6 / 3	0.91
Follow up 3 months (months)	3.2 (0.3)	2.9 (0.3)	0.013
Follow up 1 yr (months)	13 (5)	13 (2)	0.82
Larsen score (3/4/5)	1 / 2 / 10	1 / 5 / 4	0.17
FFI B	54 (21)	58 (25)	0.74
FFI C	39 (20)	50 (16)	0.16
AOFAS	36 (21)	31 (19)	0.57
VAS pain	5.8 (1.5)	6.9 (1.3)	0.11
SF-36 physical functioning	49 (28)	39 (17)	0.43
SF-36 pain	65 (19)	45 (15)	0.24

All patients had suffered from rheumatoid arthritis for a period of minimally 30 months, reported high pain scores and poor functional ability. Most patients used combination therapy at the time of surgery: 18 patients were treated with synthetic DMARDS, five with biologicals and eight with steroids. There were no significant differences between the two groups for any of the subject characteristics, except for the difference in duration of 3 months FU.

Figure 5 shows the mean and standard deviation of the outcome factors for both groups at preoperative examination, three and 12 months postoperatively. Table 2 shows the corresponding values for the outcome factors after one-year follow-up. The two way ANOVA revealed a main effect for measurement time for all outcome parameters ($p<.01$). A significant improvement in all outcome scores between preoperatively and three months postoperatively and between preoperatively and 12 months postoperatively for both groups was found. The outcome scores between three and 12 months postoperatively were not statistically significantly different. Neither main effect for groups nor an interaction was found (p-values were >.06). Furthermore, all other domains of the SF-36 revealed no statistically significant between, within and interaction effects.

Figure 5. The course of the different outcome scores within time and comparison between the two groups. In parenthesis the number of patients per group (resection/ release) with complete follow-up data per specific outcome score.

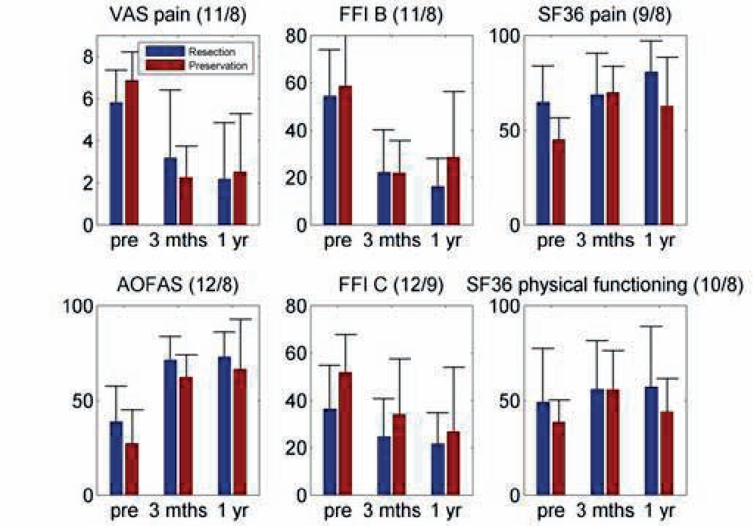


Table 2. Mean (standard deviation) of the outcome scores of MT head resection and MT head preservation group after one year FU.

	MTH resection [SD]	MTH preservation [SD]	Statistics
FFI B	16 (12)	27 (27)	p=.46
FFI C	22 (13)	27 (27)	p=.14
AOFAS score	73 (13)	64 (26)	p=.12
VAS pain	2.2 (2.6)	2.6 (2.6)	p=.83
SF 36 physical functioning	57 (32)	44 (18)	p=.47
SF 36 pain	81 (16)	63 (26)	p=.12

A decrease of the VAS pain score and FFI subscales was found in both groups. Furthermore, an increase in SF-36 subscales and the AOFAS score was found.

Analysis of difference in functional limitations and MTPJ function (item number 2 and 4 of the AOFAS score) did not show statistical significant difference (p=.76 and p=.15 respectively) between the two groups.

Nijmegen classification

Table 3 shows the postoperative clinical situation of the lesser MTPJ and soft tissues, according to the Nijmegen Classification. The Chi square test revealed no statistically difference in distribution of the classification scores between the two groups (p=.29).

Table 3. Nijmegen classification after one year FU.

	0	1	2	3
Resection	5	5	1	
Preservation	1	4	1	1

Radiological outcome

The feet in both groups showed adequately aligned lesser MTPJ on standard radiographs. With exception of one patient after MTH preservation, in which the second and third MTPJ were still radiographically dislocated (grade 3 according to the Nijmegen classification).

Among both the resection and preservation group all corrected first rays proved to remain well fused, aligned and stable, except for two patients. In one patient (MTH resection group) the first MTPJ arthrodesis led to an asymptomatic non-union. In another patient there was malalignment of the first MTPJ fusion (MTH resection group), with increased dorsoflexion position. These patients did not undergo a new procedure.

Complications

A total of 10 complications in 23 patients were reported [Table 4]. Five complications occurred within the MTH resection group. Five occurred within the preservation group. Two patients complained of a sensational impairment. Of these, one patient (resection group) reported hypersensitivity located at the medial scar of the hallux; and one patient (after MTH preservation) reported plantar paresthesia with radiation into the second to fourth ray. There were two peroperative complications. In one patient (resection group) the screw fixation of the first MTPJ fusion proved to be inadequate, and for this reason additional K-wires were applied. This eventually led to an asymptomatic non-union of this joint (as described under "radiological outcome"). In one patient (MTH preservation) rupture of the skin occurred during surgery, as result of applying to much force on an atrophied skin.

Table 4. Complications.

Complication	MTH resection	MTH preservation
Sensory deficit	1	1
Peroperative	1	1
Non-union first MTPJ	1	
Malalignment lesser MTPJ	1	2
Malalignment first MTPJ	1	
CRPS		1
Total	5	5

Four patients were found to have malalignment of one or more toes (two in the resection group). Two patients (one in both groups) demonstrated residual hyperextension deformity in one or more lesser MTPJ (grade 2 of Nijmegen classification). One patient after MTH preservation showed recurrence of the deformity in the second ray (Nijmegen classification grade 3). One patient (MTH resection) showed a malalignment of the first ray, after MTPJ fusion, as described previously.

One patient (MTH preservation) suffered from complex regional pain syndrome and was treated with different drug therapies. Currently she still suffers from this complication.

DISCUSSION

In the current randomised controlled trial, concerning the operative treatment of rheumatoid forefoot deformity, no difference in clinical and radiographic outcome between metatarsal head resection and preservation was found.

Multiple arguments can be put forward to advocate an operative method in which the function of the MTH and MTPJ is preserved (Stainsby. 1997, Briggs and Stainsby. 2001, Louwerens and Schrier. 2013). From a functional point of view resection of the MTP joints has been described as "an internal amputation". The metatarsal heads are important weight-bearing structures and with resection often relatively healthy appearing metatarsal heads (joints) are sacrificed unnecessarily (Bitzan et al. 1997). With improvement of medical strategies it is likely that these patients ask for higher demands, regarding overall function and quality of life. It is reasonable to presume that this is achieved by preserving normal function of the forefoot, including the lesser MTPJ (Patsalis et al. 1996, Toolan and Hansen. 1998, Niki et al. 2010, Krause et al. 2011, Momohara et al. 2014). By preserving the length of the metatarsal bones and relocating the plantar plate and forefoot fat pad to their normal functional position, without dividing attachments to the deep transverse metatarsal ligament and plantar aponeurosis, the weight-bearing function and the longitudinal windlass mechanism remain effective (Queally et al. 2009, Yano et al. 2013, Bass et al. 2014) .

Procedures with resection arthroplasty of the lesser MTH continue to be the most advocated standard options for the operative treatment of severe rheumatoid forefoot deformity (Hoffman. 1912, Vandeputte et al. 1999, Coughlin. 2000, Bass et al. 2014). The reported success rate and patient satisfaction of these resection arthroplasty procedures are rather divergent (Vahvanen et al. 1980, McGarvey and Johnson. 1988, Stockley et al. 1989, Hughes et al. 1991, Patsalis et al. 1996, Coughlin. 2000, Farrow et al. 2005, Thomas et al. 2005). Mid and long-term studies after resection arthroplasty procedures report a success rate of 70-90% (Craxford et al. 1982, Hamalainen and Raunio. 1997, Fuhrmann and Anders. 2001). After longer follow-up a relatively high percentage of persisting pain, callosities, recurrent deformity and bony prominence of the metatarsal stumps is reported, with a reoperation rate of 10-15%

(McGarvey and Johnson. 1988, van der Heijden et al. 1992, Saltzman et al. 1993, Patsalis et al. 1996, Hamalainen and Raunio. 1997, Tillmann. 1997, Fuhrmann and Anders. 2001, Thomas et al. 2005, Reize et al. 2006). Thomas et al. reported an average AOFAS score of 64.5, in a patient group after resection of all five MTH, with a FU of 5.5 years(Thomas et al. 2005). The current study shows significant improvement of all outcome scores after MTH resection, with a mean AOFAS score of 73 (13) and a VAS pain score of 5.8.

The level of scientific evidence supporting preservation of the MT heads, among patient with rheumatoid forefoot deformity, is rather poor (Farrow et al. 2005, Louwerens and Schrier. 2013). Current literature reports inconsistent outcome after these procedures (Trieb. 2005, Barouk and Barouk. 2007, Bolland et al. 2008, Queally et al. 2009, Niki et al. 2010, Dodd et al. 2011, Bhavikatti et al. 2012, Bass et al. 2014). Briggs and Stainsby demonstrated good subjective and objective results after a follow-up of 11 years in patients with claw toe deformity (Briggs and Stainsby. 2001). Bhavikatti et al. described results after joint preservation through Weil's shortening osteotomy, with improvement of AOFAS score from 39.8 to 88.7 and 83% no pain after a mean FU of 51 months (Bhavikatti et al. 2012). Van der Heide et al. reported an AOFAS score of 69.80 (SD= 11.8) and a FFI-score of 23.0 (SD=17.5) after a FU of 40 months, applying a surgical method identical to current study (van der Heide and Louwerens. 2010). The present study confirms considerable improvement of the AOFAS score (from 29 to 67), achieved through a MTH preserving technique. Additional outcome factors of current study are also comparable to outcome as reported in the literature.

There is a difference, however, between the MTH preserving method as applied in the present study and most of the methods used in the referred studies. In current study shortening and stress relief, in order to reduce the MTPJ, are achieved by resection of the PIPJ (the distal part of the basal phalanx) and through capsulotomy and tenotomies. The joint and the attachments of the plantar aponeurosis and the length of the metatarsal are preserved. The advantages are preservation of the integrity of the MTPJ and possibly the biomechanics of the ray. The disadvantages in practise are the risk of soft tissue damage and soft tissue complications (which actually occurred in one of the patients), as a result of too much lengthening. Furthermore, stiffness of the MTPJ, resulting from reduction of a severely damaged joints, or as a result of too much stress on the joints, may be an additional disadvantage, which did not occur in the patients participating in the current study.

No statistically significant differences in radiographic outcome between the groups were found. In contrast, Krause et al. found better sagittal alignment after a MTH resection procedure compared to MTH preservation (Krause et al. 2011). Evaluation of the joints in the sagittal plane, on a lateral weight bearing radiograph, is difficult and probably inaccurate, due to over projection of all lesser rays. At clinical examination, one year postoperatively significant malalignment of the lesser MTPJ, in the sagittal plane, was established in three patients (2 in MTH preservation group).

A rather high complication rate of 10 complications in 23 patients was found in the current study. Malalignment of the lesser MTPJ in the sagittal plane (3 patients) was the most prevalent complication. Comparison of the complications between the present study and those reported in the literature is difficult due to the variety of methods applied in these studies. Applying the identical MTPJ preserving method as in the present study, Van der Heide et al. reported a lower complication rate, with 8 complications in 54 feet, with a mean FU of 40 months (van der Heide and Louwerens. 2010).

The present study design did not show advantage of one of the applied methods. Multiple reasons might explain this. Possibly the study population was too heterogenous or the period of follow-up was too short. Randomisation may lead to application of a specific treatment in less suitable patients (e.g. MTH preservation in severely damaged MTH), which influences outcome. The applied outcome factors may be deficient in detecting difference, with limited psychometric properties. Possibly, other factors as stiffness, pressure distribution and gait pattern could have differed. However, these factors were not taken into account.

The randomised clinical trial design with different validated outcome measures, a PROM, and radiographic outcome are strengths of this study. To our knowledge no comparable study on this topic has previously been performed. Additionally, the three surgeons followed the same treatment protocol after discussion and practice during a cadaveric session (reduced performance bias), and all outcome parameters were assessed by independent researchers (limited assessor bias). The included patients are a representative clinical population. By contrast, this study has clear limitations. Although 3 centers were involved in the study, it was disappointing it took seven years to include this rather small number of patients. The prevalence of rheumatoid forefoot deformities seemed to decline dramatically by the time this study started. The primary explanation is the success of the pharmalogical treatment of rheumatoid arthritis, resulting in a rapid decline of severe forefoot deformities. The strict inclusion criteria also explain the small number of included patients with lengthy period of inclusion. Two way repeated measures, however, did not show any indication that inclusion of a higher number of patients, would prove significant difference between the two surgical procedures.

Based on the results of the present randomised study the use of both operative procedures can be equally recommended. No scientific grounds have been found to advise one of the procedures in particular. However, the study results do support the following strategy now applied at our departments. Treatment of rheumatoid forefoot deformity should be individualized. The less extensive the deformity the more tendency exists to advise a MTPJ preserving procedure, respecting and reconstructing the ‘normal’ functional anatomy. In cases with more extensive contracture of the soft tissues and important damage of the lesser MTPJ it is felt that resection-arthroplasty of the lesser MTP joints is favourable.

CONCLUSIONS

Irrespective of presented flaws, our study, with a randomised controlled design, did not show any clinical difference between MTH resecting and preserving procedures. Both procedures resulted in considerable improvement of pain and activity scores.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

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Chapter 7

Patient-reported outcome measures in hallux valgus surgery. A review of literature.

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ABSTRACT

Background: Up to a third of patients may be dissatisfied with the outcome of hallux valgus surgery. This stresses the importance of uniform and relevant outcome measures. The purpose of the current systematic review is to identify and rate available patient-reported outcome measures (PROMs) in hallux valgus surgery.

Methods: We performed a systematic literature search for outcome measures directed at hallux valgus. We searched electronic databases for relevant content according to the PRISMA standard. Eligible articles were used to give an overview of available PROMs, with qualitative evaluation of their properties.

Results: Twenty-eight eligible studies were included. Most adapted general health assessment tools, in studies on hallux valgus surgery, were the EQ5D and the SF-36 score. The visual analogue scale (VAS) was most cited as pain score. Three disease-specific outcome scores were identified: the Manchester-Oxford foot questionnaire (MOXFQ), the foot and ankle outcome score (FAOS) and the self-reported foot and ankle score (SEFAS). The MOXFQ showed the best psychometric properties.

Conclusions: The MOXFQ scores best on positively rated qualities based on our criteria. The SEFAS may be a good alternative, however it contains less items which are regarded as important by patients with foot/ ankle complaints. A relative drawback of the MOXFQ consists of the copyright licence. The VAS is the best pain score and the SF36 the best general health assessment tool. Availability in native languages and future research should lead to uniformity in application of these tools.

1. INTRODUCTION

Hallux valgus has a prevalence of 23% in adults and this increases with age [1]. Although numerous articles have been published on hallux valgus surgery, there is no consensus on the optimal surgical technique or timing of surgery. Up to a third of treated patients may be dissatisfied with the outcome of surgery [2]. This is definitely not always reflected in outcome parameters in literature, due to a lack of uniform and relevant outcome measures in hallux valgus surgery [3–5].

Patients typically want a painless greater toe when wearing conventional shoes, and it is surprising that these expectations are only partly revealed by physician-based clinical outcome scores [6]. Current outcome measures tend not to use validated patient-reported outcome measures (PROMs), but rather physician-based outcome measurements [3–5]. Traditionally, these measurement tools have been developed for research purposes, not for quantifying patient-based outcome [7]. Standardized PROMs reflect the patients' rather than the clinicians' perspective and can provide useful information on patient satisfaction. Moreover, they are independent of the surgical team [6,8].

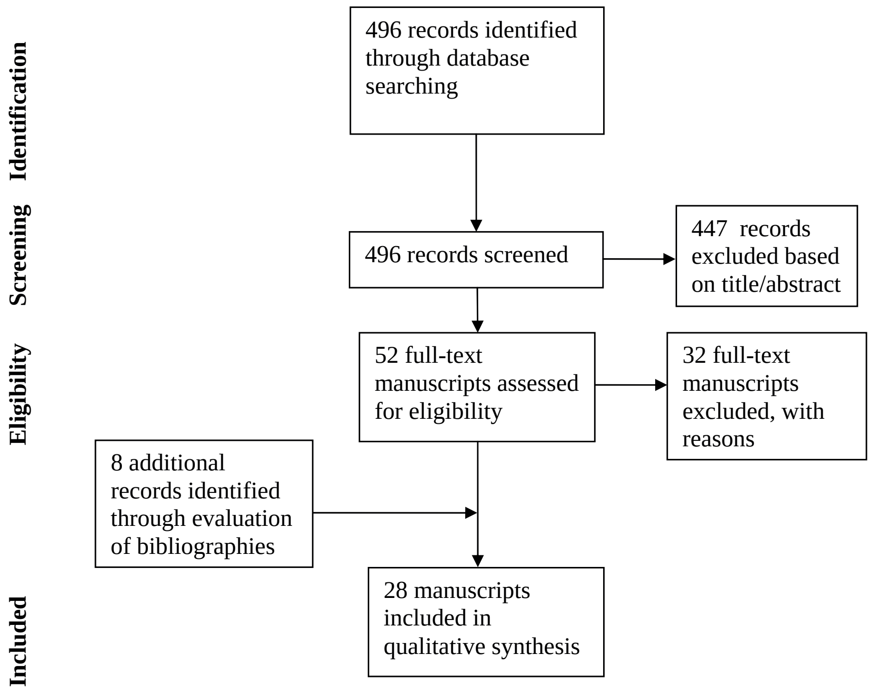
PROMs are classified into three general categories: general quality of life (QoL), pain scale and disease-specific outcome measures [9]. For various highly prevalent orthopaedic conditions, such as knee and hip osteo-arthritis, validated QoL, pain and disease specific PROMS are widely used for both research and clinical evaluation. Current literature shows the majority of scores in foot and ankle pathology have questionable validity, reliability, applicability and responsiveness [5,7,10]. The high incidence of hallux valgus surgery, the various treatment options, and the uncertainty regarding the optimal indication and timing of surgery warrant the need for consensus on outcome measurement. The purpose of current systematic review is to identify and rate available PROMs on hallux valgus surgery.

2. METHODS

The electronic databases Medline, Pubmed, Embase and Cochrane were searched systematically to identify relevant publications. Our systematic searches used the keywords "hallux valgus" OR "foot" OR "ankle", "PROM" OR "questionnaire" OR "instrument" OR "outcome measure", "validity" OR "reliability" OR "responsiveness". Our search strategy was conducted applying the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) standard [11,12]. All references in the databases were included up to June 2014. Only manuscripts written in English were included. Bibliographies of relevant citations were screened for further manuscripts of relevance. Manuscripts and references were evaluated for relevant content, with PROMs of hallux valgus as main focus. The original manuscript, reporting the development and the psychometric properties of the relevant PROM, was included. We excluded manuscripts that reported on physician based outcome scores and PROMs based on and accounting for foot-/ankle pathology, other than hallux valgus. The remaining manuscripts were systematically reviewed by two reviewers (JS and LP). All clinical patient-reported outcome scores, applied in selected manuscripts, were recorded. For evaluation PROMs were classified into three general categories: general quality of life outcome scores, pain outcome measures and disease-specific outcome measures [9].

Several manuscripts describe quality criteria for evaluation of outcome instruments [13–17]. Standardized evaluation of so-called psychometric properties of outcome instruments, promote scientific foundation of these tools. The psychometric properties of these instruments describe the relevance, quality and measurement properties. We adapted the checklist as described by Veenhof et al. and rated the included PROMs by following criteria: time to administer, ease of scoring, readability and comprehension, content validity, internal consistency, construct validity, floor/ceiling effect, reliability, agreement, responsiveness, interpretability and minimal clinically important difference (MCID) [14,16,18]. In our opinion this method covers clear outcome instrument evaluation best. All properties were rated as either "positive", "doubtful", "negative" or "unknown/unclear". To give an overview we counted the number of all positive ratings for each tool.

Fig. 1. Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flow diagram.



3. RESULTS

Initial search strategies yielded a total of 496 hits. Application of the search objective, inclusion/exclusion criteria and analysis of the bibliographies eventually resulted in 28 eligible manuscripts. These were included in this study and underwent quality assessment [Fig. 1].

Table 1 demonstrates the psychometric properties and quality of the included PROMs according to a checklist described in previous studies [14,16].

Table 1 Summary of the quality assessment of PROMs directed at hallux valgus.

	SF-36	EQ5D	NRS	VAS	MOXFQ	FAOS	SEFAS
Patient-based	+	+	+	+	+	+	+
Time to administer	−	−	+	+	+	−	+
Ease of scoring	−	−	+	+	+	+	+
Readability and comprehension	−	+	+	+	+	−	+
Content validity	+	*	*	*	+	ø	+
Internal consistency	+	*	*	*	+	+	+
Construct validity	+	*	*	*	+	+	+
Floor/ceiling effect	*	*	*	*	+	−	+
Reliability	*	*	*	*	+	+	+
Agreement	+	*	*	*	+	*	+
Responsiveness	ø	*	*	*	+	ø	+
Interpretability	+	*	*	*	+	*	*
MCID	ø	*	*	*	+	*	*
Positively rated qualities, no.	6	2	4	4	13	5	11

Abbreviations: MCID: minimal clinically important difference; SF-36: medical outcome study short form (SF) questionnaire, NRS: numeric rating scale, VAS: visual analogue scale, MOXFQ: Manchester-Oxford foot questionnaire, FAOS: foot and ankle outcome score; SEFAS: self-reported foot and ankle score; + = positive; − = negative; ø = doubtful; * = unknown/unclear.

3.1. General quality of life outcome scores (QoL)

The Medical Outcome Study Short Form (SF) questionnaire (SF-36) is the most used general health outcome measure [9]. The SF-36 consists of thirty-six items, with eight subscales per item. The original questionnaire is quite extensive, possibly leading to reduced readability and comprehension. It is rather complex to calculate the total score to provide the single index value. In 1996 the SF-12 was developed, containing twelve items [19]. The SF form has been validated for various diseases, as for hallux valgus in specific (the SF-36) [20–23]. It has a good correlation with disease-specific measures [24]. The responsiveness among patients with hallux valgus seems rather questionable [Table 1] [5,23].

EQ5D is a standardized and validated questionnaire, with five subscales (mobility, self-care, usual activities, pain/discomfort, anxiety/depression) [25–27]. It also contains a visual analogue scale on general health status. It is complex to calculate the total score to provide the single index value. Although the questionnaire has been validated for multiple disorders, it has not been validated for hallux valgus surgery [28]. This also accounts for the reliability, responsiveness and MCID [29,30]. The responsiveness is higher when compared to the SF-36 [Table 1] [29–32].

3.2. Pain outcome measures

Pain and functional (dis)ability are the most important outcome factors for surgical treatment [1]. We found two pain scales used in hallux valgus surgery. It can be objectively measured by the numeric rating scale (NRS) or visual analogue scale (VAS).

The NRS is a 11-point numeric rating system, with zero representing "no pain" and 10 representing "the worst imaginable pain". We could not retrieve any information regarding validity, responsiveness and reliability. Application of NRS for purposes of clinical research has shown variable effectiveness [Table 1] [33].

The VAS is the second most applied outcome tool in foot and ankle pathology (the American Orthopaedic Foot and Ankle Society (AOFAS) scales being the most popular) [4]. The VAS is virtually represented as a 10-cm horizontal line. The left terminus is designated "no pain", the right terminus is designated "the worst imaginable pain." The respondent marks the line at the site that characterizes the pain. The distance of the line from left terminus to the mark is measured, with centimetres representing the number of pain. The VAS is validated for various orthopaedic outcomes and has shown to be reliable [34–37]. Responsiveness has, amongst other things, been shown in a group of patients with osteoarthritis [38]. There are no specific psychometric data on hallux valgus [Table 1].

3.3. Disease-specific outcome measures

We found three disease specific outcome measures, the MOXFQ, the FAOS and the SEFAS. The Manchester-Oxford foot questionnaire (MOXFQ) is an instrument developed as an outcome measure for hallux valgus corrective surgery [23,39,40]. It consists of three domains (pain, walking/standing and social interaction) with 16 items, reported by patients. Each item is answered on a five-point Likert scale (0 to 4; '4' assigned 'most severe'; higher scores denoting higher severity). The score for each domain is calculated as the sum of each individual item score. This is expressed on a metric of 0 to 100 (100 times actual score, divided by the maximum possible domain score). The MOXFQ has already been configured to a summary score (MOXFQ-index) [41]. This score has been validated specifically for hallux valgus surgery, and has good reliability and responsiveness [3,23,31,32,41,42]. The MCID was demonstrated by Dawson et al., for each different domain [23]. These were 16, 12 and 24 for the walking/standing (seven items), pain (five items) and social interaction domains (four items), respectively. This score is more sensitive than general health measures for quantifying hallux valgus surgery. There were no floor and ceiling effects in patients undergoing foot or ankle surgery (31.3% of this group underwent a non-specified method of hallux surgery) [Table 1] [42].

The foot and ankle outcome score (FAOS) consists of five subscales, with 42 items (pain, additional symptoms, daily activities, sports/recreational activities, foot/ankle-related QoL) [43]. The items are derived from the Knee injury and Osteoarthritis Outcome Score (KOOS) [44]. The questionnaire is quite extensive, possibly leading to reduced readability and comprehension. It has been validated in the original manuscript, on patients after ankle ligament reconstruction. Recently it has been validated for patients with hallux valgus, showing acceptable reliability and responsive-ness [45,46]. However, the sports and recreation subscale of the FAOS showed little responsiveness to hallux valgus surgery. Ceiling effects were present for the ADL and sports subscale [45]. Data on MCID could not be traced [Table 1].

The self-reported foot and ankle score (SEFAS) originally was developed for assessing outcome after ankle replacement surgery, based on the New Zealand total ankle questionnaire [47]. It consists of 12 items, with 3 subscales (pain, function and additional symptoms) [48]. Eight questions are derived from the Oxford-12- hip questionnaire; 4 questions are focussed on foot/ankle pathology [39]. Recently its psychometric properties have been demonstrated among a population with foot and ankle disorders, including 91 patients with hallux disorders, who underwent surgical treatment [49]. This manuscript showed the SEFAS has good validity, reliability and responsiveness, when evaluating patients with hallux disorders. Data regarding MCID could not be found [Table 1].

Our evaluation of literature shows the American Orthopaedic Foot and Ankle Society Scales (AOFAS) are the most adapted outcome scales in foot and ankle surgery, however these scales are mostly physician-based, thus excluded from our review [4]. In addition, these scales have not been adequately validated [7,50]. Most other joint-specific PROMs (foot function index (FFI), American Academy of Orthopaedic Surgeons scale (AAOS), foot and ankle ability measure (FAAM), foot health status questionnaire (FHSQ)), directed at foot ankle pathology, are not validated for hallux valgus surgery and could therefore not be included in this review. These tools are not specifically designed for evaluation of hallux valgus surgery and lack factors that are of primary importance to the patient with a hallux valgus [51].

4. DISCUSSION

Both the MOXFQ and SEFAS show good psychometric properties when used for the assessment of hallux valgus treatment. For the SEFAS, data on the minimal clinically important difference and interpretability are currently lacking. As a result, the MOXFQ scores best on positively rated qualities based on our criteria. This score has been specifically designed for patients with hallux valgus. The SEFAS, however, may still be a good alternative as it particularly uses fewer items. Both PROMs have shown to be versatile and are also validated for other foot and ankle disorders [32]. A relative drawback of the MOXFQ consists of the copyright licence, which is required for any use of the score, with administration fees for any version [52]. Limited validated translations of both instruments have been developed until now [48,53].

The psychometric properties of the quality of life scores, demonstrate the SF-36 meets quality criteria best. It demonstrates, overall, the highest ratings in comparison to the EQ5D. There is limited evidence for the application of pain scores for rating patients with hallux valgus. The VAS has been cited most frequent in studies concerning patients with hallux valgus.

The importance of PROMs in evaluation of hallux valgus surgery is expressed by Baumhauer et al. They show outcome factors regarded by patients with foot/ankle complaints as important, differ from factors judged by physicians [7]. This suggests an inconsistency of expectations between the patient and physician. The study by Baumhauer et al. identifies 5 factors which are of critical importance to the patient (with variation between sexes and ages): limitations in walking, constant pain, activity-related pain, difficulty with prolonged standing, and inability to do a job or housework. Younger patients regarded the ability to play sports and to perform work responsibilities of additional importance. Women thought that fitting in a shoe was very important, this was not valued as much by men. The MOXFQ covers all these patient-relevant items. The SEFAS lacks items directed at prolonged standing, inability to perform work/sports and shoe fitting.

This current review has limitations. The conduct of our literature search may be incomplete, thereby excluding relevant instruments. Research focussing on evidence of outcome instruments is an ongoing process, implicating the actuality of our review may already be expired. In literature there is lack of uniformity in the use of quality criteria on systematically evaluation of outcome measurements [13–17,54–58]. The criteria we applied can be debated and no clear instructions exist how to apply these criteria [14,16]. The rating is mainly dependent on the availability of information and the quality of reporting of the specific measurement. Factors like responsiveness are often ill defined and not well assessed, making evaluation and comparison of specific scores rather difficult. We counted all positive ratings to an overall score, suggesting all different qualities are equally important. However, this is highly debatable.

An ideal PROM should be constructed as a disease-specific tool, with additional questions regarding general health/quality of life and pain [31]. It should encompass items that are relevant to the patient. The timing of obtaining a PROM depends, amongst other things, on factors like the end-stage after a specific treatment (when to perform the final PROM?). In the context of the high prevalence of hallux valgus surgery and the controversy regarding indication and timing of surgery, a well-defined and substantiated PROM is essential. This will improve the quality and comparability of scientific studies. Future research should focus on quality assessment of available PROMs, rather than development of new PROMs.

Based on available data, the MOXFQ and SEFAS are suitable PROMs for assessment of hallux valgus treatment. Which PROM will ultimately be most successful in daily clinical practice, will depend on the availability in native languages and future research comparing the MOXFQ and the SEFAS for hallux valgus treatment.

Conflict of interest statement

There are no known conflicts of interest.

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Chapter 8

Is it too early to move to full electronic PROM data collection? A randomized clinical trial comparing PROM's after hallux valgus captured by e-mail, traditional mail and telephone.

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ABSTRACT

Background: Patient reported outcome measures (PROM's) after hallux valgus surgery are used to rate the effectiveness as perceived by the patient. The interpretability of these PROM's is highly dependent on participation rate. Data capture method may be an important factor contributing to the response rate. We investigated the effect on response rate of traditional paper mail, telephone and e-mail PROM's after hallux valgus surgery.

Methods: All consecutive patients operated between January and September 2013, were identified. Included patients were randomized by envelope in three groups: traditional pen and paper mail, e-mail and telephone. They were asked to fill in a FFI and EQ-5D. Two weeks later non-responders were sent a reminder.

Results: Of the 73 included patients, 25 were approached by mail, 24 by e-mail and 24 patients by telephone. The response rate on traditional mail was highest (88%), while response on e-mail was lowest (33%). Response rate on telephone was also high (79%). Response rate on traditional mail and telephone was significantly higher ($p < 0.001$) than response on e-mail.

Conclusions: Though electronic data collection has enormous potential, this study shows that e-mail yields unacceptable low response rates. It is too early to replace traditional pen-and-paper PROM's by electronic questionnaires.

1. INTRODUCTION

Patient reported outcome measures (PROM's) collect informa-tion on the effectiveness of care as perceived by the patients and are critical to assess whether surgery really improves the health of patients. Patients are usually invited to complete standardized PROM's before surgery and at regular times postoperatively. The success of conducting a survey depends on the participation rate. A suboptimal participation rate gives rise to a possible selection bias and decreases the validity and interpretability of PROM's considerably [1,2]. Previous studies identified multiple patient characteristics associated with non-response: a language barrier, substance abuse, cognitive limitations, psychiatric diagnosis, sight deficiency, low socioeconomic status, non-white patients and patients living alone [3–5].

Data capture method may be an important factor contributing to the response rate, and various distinct methods for contacting patients are in use. Typical capture methods of PROMs include contacting patients by telephone, by e-mail, by traditional paper mail or through an appointment in the outpatient clinic.

Possible advantages of web-based PROMs are numerous: faster response, efficient data collection and management, and cost-efficiency. However, literature comparing response rate of differ-ent capture methods is scarce and current available evidence is inconclusive.

Older studies, in non-orthopedic patient groups, showed equivalent scores in pen-and-paper and computerized PROMS [6] or higher response rates in traditional pen-and-paper methods [7,8]. More recent non-orthopedic studies confirm this [9,10]. A meta-analysis by Shih [11] in 2009 described 35 studies, performed between 1992 and 2006 in all kind of scientific fields, that directly compared the response rates of traditional mail versus e-mail surveys. Shih concluded that mail survey was still superior to e-mail survey with higher response rate.

In orthopedic studies, data capture methods are compared in patient groups needing joint replacement surgery. Gakhar [12] reported no difference in response between electronic capture methods and pen-and-paper methods, while Rolfson [13] found a higher response rate on traditional pen-and-paper PROM's. Schamber [5] found that a switch from paper surveys to electronical capture methods resulted in a significant increase in PROM participation rate.

Few studies compared obtaining PROM's by telephone with other capture methods. Harris [14] compared mailed surveys and telephone interviews. He found a higher response in the telephone group and reported less missing data. Harewood [15] found a slightly higher response rate when comparing telephone with e-mail, but his study also shows that e-mail was the most cost-efficient. A recent study by Nota [16] compared mail, e-mail and telephone in terms of response rate in younger orthopedic patients after hand surgery. Nota found the highest response rate in the group of people that were interviewed by telephone; response on e-mail was lowest.

Other studies only used telephone contact as a reminder to patients that did not respond initially [17] or to identify the reason for non-response [12].

We focused on the use of PROM's in patients after hallux valgus surgery. Standardized evaluation with PROM's will help to compare different surgical techniques and help to improve patient satisfaction. Response rates in patients receiving hallux valgus surgery may differ from orthopedic patients requiring joint replacement, since patients are typically younger and the operation is less invasive, and have not been investigated before.

In this study we aim to investigate the effect of three different data capture methods on the response to PROM's used after hallux valgus surgery: traditional pen-and-paper mail, electronic mail (e-mail) and telephone.

As the population of patients receiving hallux valgus surgery is younger compared to those requiring joint replacement, we hypothesize that e-mailed questionnaires will yield the highest rates of response.

2. PATIENTS AND METHODS

2.1. Setting

The study was conducted at the Canisius Wilhelmina Hospital, a 653 bed public hospital located in Nijmegen, The Netherlands.

2.2. Design

All patients receiving hallux valgus corrective surgery between the 1st of January 2013 and the 1st of September 2013 were identified using the hospital's electronic patient database. Exclu-sion criteria were people without an e-mail address, age under 16, age above 75 years, a language barrier and inability to reach by phone for collection of the e-mail address after three attempts. Socioeconomic status, comorbidities and complications after surgery were not exclusion criteria.

Patients were contacted by phone by one of three investigators in October 2013 to collect their e-mail addresses. An e-mail in which the purpose of the study was explained, was sent to all patients on in December, 2013. The included patients were randomized by envelope via www.randomisation.com into three groups: (1) traditional pen and paper mail (mail), (2) electronic mail (e-mail) and (3) telephone. These data were recorded in non-transparent envelopes (SNOSE) [18]. The allocation sequence was concealed to the investigators. All patients were asked to fill in the validated Dutch version of the Foot Function Index (FFI) and the EQ-5D health questionnaire. The Foot Function Index (FFI) is a widely applied score, which was developed to measure the impact of foot pathology on function in terms of pain, disability and activity restriction [19,20]. It consists of twenty-three items in three subscales, with a maximum of 100 points. The EQ-5D is a standardized and validated questionnaire, with five subscales (mobility, self-care, usual activities, pain/discomfort, anxiety/ depression). It contains a numeric rating scale on general health status [21]. Patients approached by mail received an envelope containing a cover letter explaining the purpose of the study, the two PROM-questionnaires and a business-reply envelope. The envelopes were posted in December 2013. Two weeks later we sent non-responders a reminder with a new reply envelope. Patients approached electronically received an e-mail in December 2013 in which the purpose of the study was explained with the PROM questionnaires attached. After two weeks a reminder was sent, if necessary. The third group of patients was approached by telephone. The purpose of the phone call was explained and the patients were asked if they would participate. When the patient agreed in taking part, he or she was asked to answer the questions of the PROM questionnaires. The answers were digitalized by the investigator. A maximum of four attempts to reach the patient was made.

Primary outcome measure was response rate. The statistical significance between the participation rate in the three groups was analyzed with a one-way ANOVA by one the investigators.

3. RESULTS

We included 73 patients, see Fig. 1 for a CONSORT flow diagram of the present study. After randomization 25 patients were approached by mail, 24 patients by e-mail and 24 patients by telephone. There was no significant difference between groups with respect to age or PROM score, see Table 1. Twenty-two of 25 patients who were approached by traditional mail sent back the PROM-questionnaires in the reply envelope. A total of six patients did this after receiving a reminder. Nineteen of 24 patients, contacted by telephone, were willing to answer

Figure 1. Patient inclusion and randomisation.

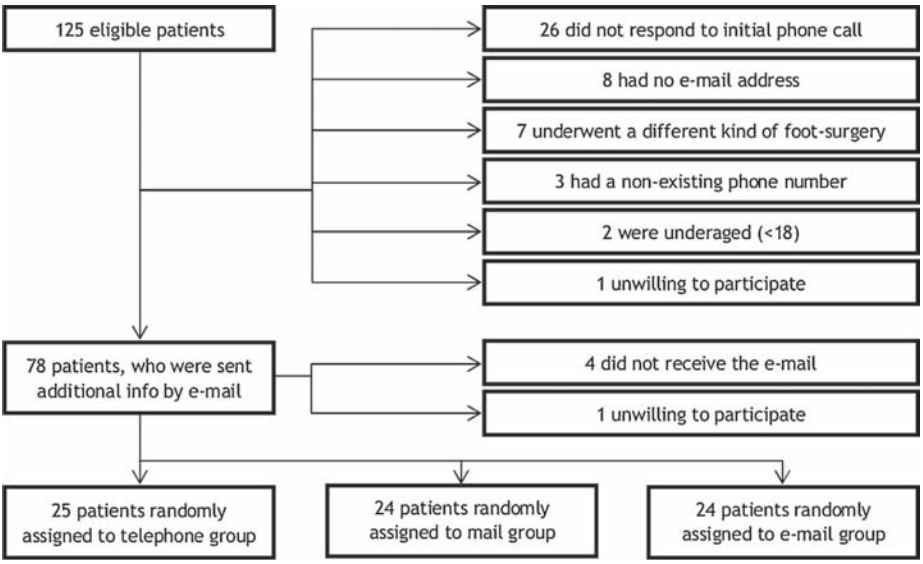

Table 1 Patient age and PROM scores in the three capture method groups.

Capture method	Mean age (years)	Score FFI	Score EQ-5D	EQ VAS
Mail	52.12 (range 17–71)	28.3	6.09	80
E-mail	50.21 (range 16–73)	26.6	6.0	86.3
Telephone	49.38 (range 17–73)	21.7	6.05	83

the PROM questionnaires. A total of three patients refused to participate in this study, and two patients did not answer the phone after four attempts. A total of eight patients, who were approached by e-mail, returned the PROM-questionnaires, of whom three did this after receiving the reminder e-mail. One of these eight patients had difficulty with her computer and came to the hospital to ask for a paper version to fill in. She sent this paper version to us by mail. See Table 2 for an overview of response rates. Response on traditional pen-and-paper mail ($p < 0.001$) and telephone ($p < 0.000$) was significantly higher than response on e-mail. The difference between response on traditional mail and response on telephone was not significant ($p = 0.414$). The response rates were not influenced by the variables age and gender.

Table 2. Participation by capture method.

Capture method	Participation	Participation percentage (%)
Telephone	19 (24)	79
Mail	22 (25)	88
E-mail	8 (24)	33.3

4. DISCUSSION

This study shows that the response rate on mailed PROM questionnaires is highest (88%), while the response of patients who received the questionnaires by e-mail was lowest (33.3%) in patients receiving hallux valgus surgery. The response rate by telephone is relatively high with 79% response. The other variables (age and gender) did not influence the response rate in this study. Although our results are similar to those in older studies [22–24], we were surprised by low response rate by e-mail. Most previous studies were performed in the 1990s, and the use of internet has improved since [25].

A high response rate is crucial for correct evaluation of PROMs because missing data are not random [26]. Results in a study performed by Iman showed that dissatisfied patients were less likely to respond to questionnaires, which suggest that there may be an over-representation of satisfied patients [27]. There is no satisfactory statistical solution to deal with missing data that may not be at random. Moreover, statistical power is stronger with higher response rates [27]. As a rule of thumb, a loss to follow-up of more than 20% probably leads to assessment bias [28,29]. However, a low response rate does not simply mean that the data are inaccurate, they may also be less reliable. Prior research showed that a response rate of 20% in some settings may yield the reliability of the data [30,31].

So why do e-mailed questionnaires yield lower response rates than the traditional on paper questionnaires, even with rapidly growing internet demographics?

There are a number of plausible explanations put forward by Palmblad et al. [32]. First, electronic data collection is not suitable for all types of patients. Patient populations might vary in physical and mental health status, age and experience with technology. Secondly, e-mails do not have a physical form and therefore do not physically show up on the patients desk. This makes it less likely for e-mail to receive the patients full attention. Nowadays people receive large numbers of e-mails, which makes a survey e-mail less high-profile, so it can be discarded easily. An additional problem is that e-mail is not always anonymized, which could influence response rate. In our study we asked the patients to fill in their name and date of birth on the paper version of the surveys, but nine patients sent back the surveys anonymously. This could indicate that patients prefer responding to PROM's anonymously. This is surprising, because this prevents the care provider to act upon a bad PROM outcome score.

Electronic surveys do provide a faster reaction time than traditional on paper surveys. Yun [22] collected over 80% of the e-mail responses in his investigation within three days after the initial contact; most responses were received on the day the initial e-mail was sent. Multiple contacts improve response rates, and it is advisable to send a second e-mail one or two weeks after the initial e-mail as a reminder.

This study has its limitations. There was a significant difference between groups in male-female ratio, which might harm the validity of our findings. However, previous authors showed that gender is not associated with non-response to PROM's [4,5]. The included patients represented a narrow range of ethnicities and socioeconomic status. This might limit the generalizability of the study and the results might not be applicable to patients with a language barrier, substance abuse, sight deficiency or psychiatric diagnosis. Another limitation is that our study size is relatively small. We did not perform a power study prior to the start of our study. A greater number of included patients may have improved the robustness of the study. The magnitude of the effect size is such that a larger study probably would not alter the results of the study. In our view, future research should focus on improved ways of electronic data collection in order to facilitate electronic data collection. Perhaps the use of a shorter PROM might facilitate the use of electronic capture methods especially if the participant use hand-held devices.

Better ways of data collection are essential for improving quality of care, and this is critical in surgeries like hallux valgus corrective surgery. Although electronic data collection has enormous potential for collecting PROMs, a major drawback of e-mail is its non-physical form which causes patients to discard it. New methods of electronic data collection should have an easy response design, to facilitate a swift response and improve response rates. Roberts et al. [33] showed in a pilot study that the combination of an SMS reminder and access to a

Wi-Fi enabled tablet computer in the clinic setting enabled 94% of elective orthopedic patients to complete a PROM. To our knowledge, there are no studies that compare response rate in web-based PROM's versus e-mailed PROM's.

The current low response rate of PROMs using e-mail in patients receiving hallux valgus surgery suggests that it is too early to replace traditional pen-and-paper PROM's by electronic ques-tionnaires.

Disclosure

Each author has participated in the writing of the manuscript, and assumes full responsibility for the content of the manuscript. There are no conflicts of interest. No funds were received in support of this study.

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Chapter 9

General discussion

The found prevalence of foot pain in the adult general population ranges from 22% to 25%(20)(15). Foot pain may impair mobility and decrease the sense of well-being (22). A variety of different disorders may result in foot pain. Early treatment helps maintain the patient's ambulatory status and prevents irreversible pathology (23).

The main goal of this thesis was to evaluate the standard of present nomenclature (definition) of specific forefoot disorders and the treatment of these disorders. The studies were specifically focussed on lesser toe deformities and rheumatoid forefoot deformity. This thesis includes two clinical studies, one concerning the operative treatment of claw toe deformity and a study concerning the operative treatment of rheumatoid forefoot deformity.

General appraisal of existent scientific data on forefoot problems demonstrate limited higher quality studies, with a lack of uniformity. It is of great importance that general knowledge concerning the treatment of forefoot problems expands, resulting in the improvement of care.

CHAPTER 2

A wide range of definitions of lesser toe deformities is reported in the literature (9)(1)(17,19)(18). The same lack of uniformity also accounts for the treatment modalities of lesser toe deformities (9). We evaluated the standards in Dutch orthopaedic practice on this topic, by sending a questionnaire to all departments. The results were compared to the standards (algorithms) by RA Mann and MJ Coughlin (2,3).

Our data can be considered as a representative sample of Dutch orthopaedic surgeons (75% response rate). The found definition of hammer and claw toe only conformed in 24% and 9% of the cases, respectively, with the definitions as adopted by Coughlin and Mann. A deformity described as a hammer toe by one department, would be described as a hammer toe by another. Particularly, the inclusion of the position of the metatarsophalangeal (MTP) joint as criterion for hammer or claw toe varied enormously. Twenty percent of respondents stated that they do not differentiate between a hammer and claw toe.

Our study also reported on the operative strategies which are applied in the Dutch practice. Most respondents considered proximal interphalangeal (PIP) joint resection as the gold standard for the treatment of a rigid hammer toe deformity, as in accordance with Coughlin and Mann. However, also PIP joint fusion was a frequently applied surgical method. The confusion in definitions might explain that in some institutions the treatment of a hammer toe is the same as the treatment of a claw toe deformity in another institution. We concluded that limited consensus on definitions and treatment of lesser toe deformities exists in Dutch orthopedic practice. Only if a consensus on definitions of the different lesser toe deformities is reached and applied, can treatment results be correctly interpreted and improved.

CHAPTER 3

We performed a study in which we evaluated applied definitions of lesser toe deformities in scientific literature. Despite the fact these are common deformities in general orthopedic practice little consensus on definitions was found. This lack of uniformity might be explained by diversity of opinions regarding the pathophysiological process underlying the deformities (13)(17). Additionally, the deformity may be described solely on the basis of the position of certain joints without taking into account the flexibility of these joints. Opinions are experienced based and the quality of evidence is low.

In order to provide clarity and the basis for further research, we proposed a definition of hammer toe and claw toe deformity in the discussion in this literature study. Again, such a proposal is experience based. It is suggested that in the case of hammertoe deformity the MTP joint is positioned in dorsiflexion, but the joint is still flexible allowing plantarflexion. In case of a clawed toe the MTP joint has become stiffened in an extended position. This distinction is found important because the fixed extended position of the MTP joint might give rise to pain in the plantar aspect of the MT head (MTH) due to biomechanical overload, whilst this is not the case in the case of a flexible MTP joint. In both conditions the PIP joint exhibits a flexed position. It is assumed that the hammer toe and the claw toe can be different stages in the same pathophysiological process; thereby the hammer toe preceeds the development of a claw toe deformity. This proposal of the definitions of hammer and claw toe might lead to promotion of uniformity and thus a better set-up of future clinical trials/studies.

CHAPTER 4

The conclusions of the previous study triggered us on performing a randomized clinical trial, in which a PIP joint resection was compared with a PIP joint fusion. All patients included in this multi-centric study suffered from one or more rigid PIP joint flexion deformities. In addition to the PIP joint procedure a MTP joint release was performed if deemed necessary. To our knowledge, this is the first randomized trial on this subject. Twenty-six patients (39 toes) were included in the PIP joint resection group and 29 (50 toes) in the PIP joint fusion group. No significant differences in AOFAS scale, the FFI and VAS could be detected, after one year of follow-up. Thus, the clinical outcome of both procedures was found to be similar. Both procedures resulted in a good to excellent outcome in pain and activity scores. The only statistically significant difference was found regarding the toe alignment in the sagittal plane, in favor of PIP joint fusion. The clinical implications of this finding remains unclear.

CHAPTER 5

Rheumatoid arthritis is recognized as an important cause of forefoot problems, despite significant improvement of pharmacological treatment that has been achieved over the last decade (5,11,12,14,16). Our literature study provided an overview of the pathophysiology and operative treatment options of rheumatoid forefoot problems. The gold standard in the treatment of severe deformity of the lesser MTP joints remains to be a surgical procedure in which all the metatarsal heads are resected (4). From a biomechanical point of view and considering the fact that not all lesser MTP joints are as severely diseased, it might be more advantageous to perform an operation preserving the MTP joints. From this review we learned that no comparative prospective outcome studies had been performed on evaluation of these two different surgical methods.

CHAPTER 6

The conclusions of the previous study triggered us on performing a randomized clinical trial, in which a MTH resecting procedure was compared with a MTH preserving procedure (as described by Louwerens et al.) (21). All patients included in this multi-centric study suffered from an established erosive rheumatoid arthritic forefoot deformity, resulting in metatarsalgia. All participating surgeons applied the same operative procedures, after practicing at a cadaveric session. All patients underwent fusion of the first MTP joint. Fifteen patients were treated according to the method of MTH resection and 14 underwent MTH preservation. Three patients were excluded and three patients withdrew from the study. Eventually 23 patients (10 in the MTH preservation group) were analysed.

After one year of follow-up no statistically significant differences in AOFAS score and additional outcome factors were found. Analysis of the difference in functional limitations and MTP joint function (item number 2 and 4 of the AOFAS score) did not show a statistical significant difference between the two groups. The feet in both groups showed adequately aligned lesser MTP joints on standard radiographs, with exception of one patient after MTH preservation. Both procedures resulted in considerable improvement of pain and activity scores. From a scientific point of view it must be concluded that one operative method cannot be recommended as better than the other. From an experience based point of view the authors did learn from this study. With the MTH preserving method the biomechanical function of the foot is maintained. The participating surgeons became convinced to advising a more tailored approach on a patient with rheumatoid forefoot deformity. The less extensive the deformity, with less destruction of the MTH, the more the tendency exists to advise a MTP joint preserving procedure, respecting and reconstructing the normal functional anatomy.

The more severe the contracture of the soft tissues, with important damage of the lesser MTP joints, the more it is felt that resection-arthroplasty of the lesser MTP joints is required.

CHAPTER 7

After performing several studies we recognized no specific forefoot outcome scores existed, despite a current trend towards increasing the application of validated and standardized Patient Reported Outcome Measures (PROMs)(10). This encouraged us to perform a literature study on PROMs directed at patients with hallux valgus, as these outcome tools might be applied for general forefoot deformities. In our study twenty-eight eligible studies were included and evaluated. The psychometric properties of these instruments describe the relevance, quality and measurement properties. The Manchester-Oxford foot questionnaire (MOXFQ) showed the best psychometric properties and was specifically designed as an outcome measure for hallux valgus corrective surgery (7)(6,8). The self-reported foot and ankle score (SEFAS) may be an good alternative, however it contains less items which are regarded as important by patients with foot/ ankle complaints. A relative drawback of the MOXFQ is the copyright license.

CHAPTER 8

The PROM data capture method may be an important factor contributing to the response rate, and various distinct methods for contacting patients are in use. A suboptimal participation rate gives rise to a possible selection bias and decreases the validity and interpretability of PROMs considerably . We evaluated which PROM data capture method resulted in the highest response rate, by randomization in three different methods, amongst a patient population after hallux valgus surgery (10).

Of the 73 included and randomized patients, 25 were approached by mail, 24 by email and 24 patients by telephone. The response rate from the traditional mail was highest, with 88%. Response rate from the telephone was 79%, while response from the email was lowest, with 33%. Age and gender did not influence the response rate in this study.

Though electronic data collection has enormous potential, this study showed that email yields an unacceptable low response rates on PROMs. Limited anonymity by using email might be a factor which explains this low response rate. It is too early to replace traditional pen-and-paper PROMs by electronic questionnaires. Better ways of data collection are essential for improving the quality of care. Probable accessibility of a computer in the clinic setting might further enhance the response rate.

FUTURE PERSPECTIVES

It is the author's opinion that in general orthopaedic practice forefoot problems are occasionally underestimated and misinterpreted, leading to inadequate treatment. There may be a discrepancy between the significance of foot and ankle problems on one hand and the expertise and attention on the other. This could have various reasons.

More research should be performed directed at forefoot problems. As a result of aging, wrong foot wear and sports activities the prevalence of forefoot problems will rise. This asks for a better support for the applied definitions, treatment strategies and outcome. A validated outcome tool, with adequate psychometric properties, specifically designed for forefoot problems, should be developed and adopted. During orthopaedic training programmes more emphasis should be put on foot and ankle problems and treatment.

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Chapter 10

Summary

Samenvatting

Question 1. Is there any consensus on definition and treatment of lesser toe deformities in Dutch orthopaedic practice?

A complete absence of consensus was found after evaluation of Dutch orthopaedic practice, by means of a digital questionnaire. A wide variation of definitions and treatment modalities were reported for claw, hammer and mallet toes. The results of this questionnaire reveal that there is an evident need for clear definitions of these lesser toe abnormalities.

Question 2. What are the general accepted definitions for hammer, claw and mallet toe?

A remarkable variation of definitions of hammer, claw and mallet toes was found in the literature. We proposed that extension of the metatarsophalangeal (MTP) joint should be the discriminating factor between a hammer and claw toe. A hammer toe is defined as a rigid flexion deformity of the proximal interphalangeal joint (PIPJ); a claw toe has an additional rigid extension deformity of the MTPJ. A mallet toe consists of a rigid distal interphalangeal joint deformity.

Question 3. Is there a difference in outcome between PIP joint resection and PIP joint fusion treating patients with PIP joint flexion deformity?

Our randomized clinical trial demonstrated no clinical difference between PIP joint resection and fusion, as surgical treatment for PIP joint flexion deformity. Both procedures resulted in a good to excellent outcome in pain and activity scores. However, a statistically significant difference was found regarding the toe alignment in the sagittal plane, in favor of the PIP joint fusion. It remains disputable if this better alignment would justify PIPJ fusion as a preferred procedure.

Question 4. Is there any consensus on diagnosis and treatment of rheumatoid forefoot deformity in literature?

We performed an extensive literature study which demonstrated poor scientific data on rheumatoid forefoot problems. Metatarsal head (MTH) resection continues to be the most advocated procedure for rheumatoid forefoot deformity. However, improved pharmacological treatment may result in less destruction of the MTH, which legitimates a MTH saving procedure. Actually, there are no differences in the pathophysiologic process of lesser toe deformities between rheumatoid and non-rheumatoid patients. Within this view, surgical treatment should be similar. By choice individual patient-related factors should be a guideline in the decisional process.

Question 5. Is there a difference in outcome between MTP joint resection or preservation in the treatment of rheumatoid forefoot deformity?

Our randomized clinical trial demonstrated neither clinical nor radiographic differences between MTH resection and MTH preservation, as surgical treatment for rheumatoid forefoot deformity. Both procedures resulted in considerable improvement of pain and activity scores. Treatment of rheumatoid forefoot deformity should be individualized. A MTP joint preserving procedure is advised in the case of a less severe deformity if the soft tissue has sufficient quality. If there is a more destructed MTP joint with inadequate soft tissue, then a MTP joint resection procedure is the recommended treatment. This latter procedure is also regarded as technically favorable.

Question 6. What is the most appropriate PROM measuring outcome after treatment of hallux valgus?

Our literature study showed that the Manchester-Oxford foot questionnaire (MOXFQ) scored best on specific psychometric criteria. The self-reported foot and ankle score (SEFAS) may be an good alternative, however it contains less items which are regarded as important by patients with foot/ ankle complaints.

Question 7. Which method of obtaining a PROM results in highest response rate?

Our randomized study showed that the response rate, of patients who were asked to fill out PROMs, was significantly higher from traditional mail and telephone, than the response from email. Age and gender did not influence the response rate in our study. Thus, the effect of a complete switch to electronic questionnaires may have a negative impact on the response rates.

SAMENVATTING

Onderzoeksvraag 1. Bestaat er consensus over de definitie en behandeling van kleine teenafwijkingen binnen de Nederlandse orthopedische praktijk?

Na evaluatie van de resultaten van een digitale enquête, die door meerdere Nederlandse orthopedisch chirurgen is ingevuld, blijkt dat er geen consensus op dit gebied bestaat. Er werd een grote variatie in de toegepaste definitie en behandeling van hamer-, klauw- en mallettenen gevonden. Hieruit werd geconcludeerd dat er een duidelijke behoefte bestaat aan uniformiteit in de definitie en behandeling van kleine teenafwijkingen.

Onderzoeksvraag 2. Wat zijn de algemeen geaccepteerde definities voor een hamer-, klauw- en malletteen?

Een grote variatie aan toegepaste definities voor hamer-, klauw en malletteen werd gevonden in de wetenschappelijke literatuur. In het onderhavige artikel wordt voorgesteld dat een extensie- stand in het metatarsophalangeale (MTP) gewricht de onderscheidende factor moet zijn tussen een hamer- en klauwteen. Een hamerteen wordt gedefinieerd als een rigide flexie-deformiteit van het proximale interphalangeale (PIP) gewricht; een klauwteen heeft daarnaast nog een rigide extensie-deformiteit van het MTP-gewricht. Een malletteen bestaat uit een rigide flexie-deformiteit van het distale interphalangeale gewricht, bij een verder normale stand van het PIP- en MTP-gewricht.

Onderzoeksvraag 3. Is er een verschil in uitkomst tussen een PIP-resectie en PIP-fusie in de behandeling van patiënten met klauwtenen?

De uitgevoerde gerandomiseerde klinische studie liet geen verschillen in uitkomst zien tussen PIP-resectie en –fusie, in de behandeling van klauwtenen. Beide procedures resulteerden in goede tot excellente uitkomsten op het gebied van pijn en functie. Er werd echter wel een statistisch significant verschil gevonden in de stand van de teen, in het sagittale vlak, ten faveure van de PIP-fusie. Het is onduidelijk of PIP-fusie hierdoor de methode van eerste keuze moet zijn in deze groep patiënten.

Onderzoeksvraag 4. Bestaat er consensus over de diagnose en behandeling van reuma-voorvoet afwijkingen in de wetenschappelijke literatuur?

Er werd een literatuurstudie verricht, waarbij er weinig methodologisch sterke data gevonden werden op het gebied van reuma-voorvoet deformiteiten. Resectie van de kopjes van de metatarsalia wordt nog steeds het meest geadviseerd als methode voor de behandeling van patiënten met een reuma-voorvoet deformiteit. Echter, het succes van de farmacologische behandeling van reuma-patiënten kan leiden tot afname van de destructie van de kopjes van de metatarsalia. Hierdoor lijkt een minder radicale procedure, met het sparen van de kopjes en behoud van de gewrichten, de voorkeur te krijgen.

Het pathofysiologische proces welke leidt tot klauwtenen met metatarsalgie, lijkt hetzelfde te zijn in reuma- en niet-reuma-patiënten. Hierdoor zou de chirurgische behandeling van deze twee groepen eigenlijk gelijk moeten zijn. Patiënt- factoren moeten uiteindelijk doorslaggevend zijn in de keuze voor de specifieke behandelmethode.

Onderzoeksvraag 5. Is er een verschil in uitkomst tussen resectie en sparen van het MTP-gewricht bij de behandeling van patiënten met een reuma-voorvoetafwijking?

Een gerandomiseerde klinische studie liet geen klinische of radiologische verschillen zien tussen patiënten met een reuma-voorvoet deformiteit, die werden geopereerd volgens een methode waarbij het MTP-gewricht gereseceerd of gespaard werd. Beide procedures resulteerden in aanzienlijke afname van pijn en toename van mobiliteit.

De auteurs proberen een klinisch relevant behandeladvies, op basis van de ervaringen opgedaan bij het uitvoeren van deze studie en op basis van de resultaten, te formuleren. Het advies is om de behandeling van een patient met een reuma-voorvoet deformiteit te individualiseren. Een MTP-gewricht sparende methode wordt geadviseerd indien een minderheid van de gewrichten zijn aangedaan en er sprake is van een goede wekedelen situatie. In het geval van uitgebreide aantasting en deformiteit van een meerderheid van de gewrichten, in combinatie met een ongunstige situatie van de wekedelen, wordt resectie van het MTP-gewricht als procedure geadviseerd. Deze methode wordt ook als een technisch gemakkelijkere methode beschouwd.

Onderzoeksvraag 6. Wat is de meest geschikte PROM voor het beoordelen van de uitkomst van de behandeling van hallux valgus?

De uitgevoerde literatuur-studie liet zien dat de Manchester-Oxford Foot Questionnaire (MOXFQ) de beste psychometrische eigenschappen heeft. De Self- Reported Foot and Ankle Score (SEFAS) kan een goed alternatief zijn, echter deze bevat minder items die door de patiënt met voet-/enkelklachten als belangrijk worden beschouwd.

Onderzoeksvraag 7. Welke methode in het verkrijgen van PROM's resulteert in het hoogste respons-percentage?

Onze gerandomiseerde studie liet zien dat het respons-percentage, van patiënten die werden verzocht een PROM in te vullen, significant hoger was indien deze per post of telefoon werd aangeboden, ten opzichte van het aanbieden per email. Geslacht en leeftijd speelden geen rol in de verklaring van dit verschil. Concluderend, de volledige overgang naar digitale vragenlijsten kan een negatief gevolg hebben op het respons-percentage.

Addendum

Scorelijsten: AOFAS score, SF-36,
Foot Function Index (FFI)

Chapter Textbook Efort 2014
"Lesser toe deformities".

List of publications

Dankwoord

Curriculum Vitae

SCORELIJSTEN

AOFAS - score

AOFAS Lesser Toe Metatarsophalangeal-Interphalangeal Scale		
Pijn (40 punten)		
Geen	☐	40
Mild/af en toe	☐	30
Gematigd/dagelijks	☐	20
Ernstig/bijna altijd	☐	0
Functie (45 punten)		
Beperkingen activiteiten		
Geen beperkingen	☐	10
Geen beperkingen dagelijkse activiteiten, zoals werk, lichte beperkingen in recreatieve activiteiten	☐	7
Lichte beperkingen dagelijks werk en bezigheden	☐	4
Ernstige beperkingen dagelijks werk en bezigheden	☐	0
Eisen schoeisel		
Normaal schoeisel, zonder zolen	☐	10
Gemakkelijk schoeisel, steunzool	☐	5
Aangepast schoeisel of brace	☐	0
ROM MTP-gewricht (dorsoflexie plus plantairflexie)		
Normale of geringe beperking (75° of meer)	☐	10
Matige beperking (30-74 °)	☐	5
Ernstige beperking (< 30 °)	☐	0
ROM IP-gewricht (plantairflexie)		
Geen beperking	☐	5
Ernstige beperking (<10 °)	☐	0
MTP/IP- stabiliteit (alle richtingen)		
Stabiel	☐	5
Duidelijk instabiel of te luxeren	☐	0
Callus gerelateerd aan MTP/IP (dig 2-5)		
Geen callus of asymptomatisch	☐	5
Callus, symptomatisch	☐	0
Alignment (15 punten)		
Goed alignement dig 2-5	☐	15
Redelijk, geringe malalignment dig 2-5, asymptomatisch	☐	8
Slecht, symptomatische malalignment	☐	0
Totaal (0-100 punten)		

SF-36 GEZONDHEIDSTOESTAND VRAGENLIJST

INSTRUCTIE: Deze vragenlijst gaat over uw standpunten t.a.v. uw gezondheid. Met behulp van deze gegevens kan worden bijgehouden hoe u zich voelt en hoe goed u in staat bent uw gebruikelijke bezigheden uit te voeren.

Beantwoord elke vraag door het antwoord op de aangegeven wijze te markeren. Als u niet zeker weet hoe u een vraag moet beantwoorden, geef dan het best mogelijke antwoord.

1. Hoe zou u over het algemeen uw gezondheid noemen?

(omcirkel één cijfer)

Uitstekend	1
Zeer goed	2
Goed	3
Matig	4
Slecht	5

2. Hoe beoordeelt u nu uw gezondheid over het algemeen, vergeleken met een jaar geleden?

(omcirkel één cijfer)

Veel beter nu dan een jaar geleden	1
Wat beter nu dan een jaar geleden	2
Ongeveer hetzelfde nu als een jaar geleden . . .	3
Wat slechter nu dan een jaar geleden	4
Veel slechter nu dan een jaar geleden	5

3. De volgende vragen gaan over bezigheden die u misschien doet op een doorsnee dag. Wordt u door uw gezondheid op dit moment beperkt bij deze bezigheden? Zo ja, in welke mate?

(omcirkel één cijfer op elke regel)

BEZIGHEDEN	**Ja, ernstig beperkt**	**Ja, een beetje beperkt**	**Nee, helemaal niet beperkt**
a. **Forse inspanning**, zoals hardlopen, tillen van zware voorwerpen, een veeleisende sport beoefenen	1	2	3
b. **Matige inspanning**, zoals een tafel verplaatsen, stofzuigen, zwemmen of fietsen	1	2	3
c. Boodschappen tillen of dragen	1	2	3
d. **Een paar** trappen oplopen	1	2	3
e. **Eén** trap oplopen	1	2	3
f. Bukken, knielen of hurken	1	2	3
g. **Meer dan een kilometer** lopen	1	2	3
h. **Een paar honderd meter** lopen	1	2	3
i. Ongeveer **honderd meter** lopen	1	2	3
j. Uzelf wassen of aankleden	1	2	3

4. Heeft u in de afgelopen 4 weken, een van de volgende problemen bij uw werk of andere dagelijkse bezigheden gehad, ten gevolge van uw lichamelijke gezondheid?

(omcirkel één cijfer op elke regel)

	JA	**NEE**
a. U besteedde **minder tijd** aan werk of andere bezigheden	1	2
b. U heeft **minder bereikt** dan u zou willen	1	2
c. U was beperkt in het **soort** werk of andere bezigheden	1	2
d. U had **moeite** om uw werk of andere bezigheden uit te voeren (het kostte u bv. extra inspanning)	1	2

5. Heeft u in de afgelopen 4 weken, een van de volgende problemen ondervonden bij uw werk of andere dagelijkse bezigheden ten gevolge van emotionele problemen (zoals depressieve of angstige gevoelens)?

(omcirkel één cijfer op elke regel)

	JA	**NEE**
a. U besteedde **minder tijd** aan werk of andere bezigheden	1	2
b. U heeft **minder bereikt** dan u zou willen	1	2
c. U deed uw werk of andere bezigheden niet zo **zorgvuldig** als gewoonlijk	1	2

6. In hoeverre hebben uw lichamelijke gezondheid of emotionele problemen u gedurende de afgelopen 4 weken gehinderd in uw normale omgang met familie, vrienden of buren, of bij activiteiten in groepsverband?

(omcirkel één cijfer)

Helemaal niet 1

Enigszins 2

Nogal 3

Veel 4

Heel erg veel 5

7. Hoeveel lichamelijke pijn heeft u de afgelopen 4 weken gehad?

(omcirkel één cijfer)

Geen 1

Heel licht 2

Licht 3

Nogal 4

Ernstig 5

Heel ernstig 6

8. In welke mate bent u de afgelopen 4 weken door pijn gehinderd in uw normale werk (zowel werk buitenshuis als huishoudelijk werk)?

(omcirkel één cijfer)

Helemaal niet	1
Een klein beetje	2
Nogal	3
Veel	4
Heel erg veel	5

9. Deze vragen gaan over hoe u zich voelt en hoe het met u ging in de afgelopen 4 weken. Wilt u a.u.b. bij elke vraag het antwoord geven dat het best benadert hoe u zich voelde. Hoe vaak gedurende de afgelopen 4 weken

(omcirkel één cijfer op elke regel)

	altijd	**meestal**	**vaak**	**soms**	**zelden**	**nooit**
a. Voelde u zich levenslustig?	1	2	3	4	5	6
b. Was u erg zenuwachtig?	1	2	3	4	5	6
c. Zat u zo in de put dat niets u kon opvrolijken?	1	2	3	4	5	6
d. Voelde u zich rustig en tevreden?	1	2	3	4	5	6
e. Had u veel energie?	1	2	3	4	5	6
f. Voelde u zich somber en neerslachtig?	1	2	3	4	5	6
g. Voelde u zich uitgeput?	1	2	3	4	5	6
h. Was u een gelukkig mens?	1	2	3	4	5	6
i. Voelde u zich moe?	1	2	3	4	5	6

10. Hoe vaak hebben uw lichamelijke gezondheid of emotionele problemen u gedurende de afgelopen 4 weken gehinderd bij uw sociale activiteiten (zoals vrienden of familie bezoeken, etc)?

(omcirkel één cijfer)

Altijd 1

Meestal 2

Soms 3

Zelden 4

Nooit 5

11. Hoe JUIST of ONJUIST is elk van de volgende uitspraken voor u?

(omcirkel één cijfer op elke regel)

	volkomen juist	**grotendeels juist**	**weet ik niet**	**grotendeels onjuist**	**volkomen onjuist**
a. Ik lijk wat gemakkelijker ziek te worden	1	2	3	4	5
b. Ik ben even gezond als andere mensen	1	2	3	4	5
c. Ik verwacht dat mijn gezondheid achteruit zal gaan	1	2	3	4	5
d. Mijn gezondheid is uitstekend	1	2	3	4	5

VOETPIJN EN BEPERKINGEN INDEX = FOOT FUNCTION INDEX

(E. Budiman-Mak et al. 1991, modificatie volgens K.J. Gorter et al.)

VRAGENLIJST VOOR MENSEN MET VOETKLACHTEN

Datum : ___ ___ _______

VOETPIJN EN BEPERKINGEN INDEX

Geachte mevrouw, meneer,

Wij verzoeken u de vragen op de volgende pagina's te beantwoorden. Met behulp van uw antwoorden kan de behandelend orthopaedisch chirurg het verloop van uw voetklachten beter volgen.

Het invullen van de vragenlijst duurt ongeveer 10 minuten. Leest u voor het invullen eerst de bijgaande instructies.

De ingevulde lijst moet u meenemen naar het eerst volgende bezoek aan uw behandelend orthopaedisch chirurg.

Hartelijke dank.

Instructies voor het invullen

De vragen hebben betrekking op de gevolgen van **uw voetklachten in de afgelopen week,** op uw dagelijks functioneren.

Streep bij elke vraag het antwoord aan dat het beste bij uw situatie past. Als u niet zeker weet hoe u een vraag moet beantwoorden, geef dan het best mogelijke antwoord.

Voorbeeld:

Als u de afgelopen week, als gevolg van uw voetklachten, slechts *zelden* schoenen droeg wanneer u in huis liep, dan geeft u dat als volgt aan:

Antwoord: ***Vraag:***	***nooit***	***zelden***	***af en toe***	***meestal***	***altijd***	***niet van toepassing***
Hoe vaak droeg u schoenen wanneer u in huis liep?	❒	❒	❒	❒	❒	❒

Het kan voorkomen, dat de uitspraak niet op u van toepassing is, omdat u de afgelopen week in het ziekenhuis opgenomen was en dus niet **binnenshuis** met schoenen kòn lopen. U kruist dan het hokje helemaal rechts **"niet van toepassing"** aan.

Voorbeeld:

Vraag:	*Antwoord:*	*nooit*	*zelden*	*af en toe*	*meestal*	*altijd*	*niet van toepassing*
Hoe vaak droeg u schoenen wanneer u in huis liep?		❐	❐	❐	❐	❐	❐

U kruist eveneens "niet van toepassing" aan als u geen schoenen droeg, niet vanwege uw voetklachten maar omdat u bijvoorbeeld griep had.

Op de volgende pagina begint de vragenlijst.

B. PIJN

Wilt u bij de volgende vragen alleen een antwoord geven, als dit antwoord met uw voetklachten samenhangt; als dat niet het geval is, kruist u "niet van toepassing" aan.

Vraag:
Hoeveel pijn had u in de afgelopen week aan uw voet in de volgende situaties?

	Geen pijn	**enige pijn**	**nogal wat pijn**	**veel pijn**	**niet te verdragen pijn**	**niet van toepassing**
B1 Toen deze op zijn ergst was?	❐	❐	❐	❐	❐	❐
B2 Voor u uit bed kwam 's morgens?	❐	❐	❐	❐	❐	❐
B3 Bij **lopen** op blote voeten?	❐	❐	❐	❐	❐	❐
B4 Bij **staan** op blote voeten?	❐	❐	❐	❐	❐	❐
B5 Bij **lopen** met schoenen aan?	❐	❐	❐	❐	❐	❐
B6 Bij **staan** met schoenen aan?	❐	❐	❐	❐	❐	❐
B7 Bij **lopen** met inlays of aangepaste binnenzolen?	❐	❐	❐	❐	❐	❐
B8 Bij **staan** met inlays of aangepaste binnenzolen?	❐	❐	❐	❐	❐	❐
B9 Aan het einde van de dag?	❐	❐	❐	❐	❐	❐

Let op: *Als èèn of meerdere situaties niet voorkwamen (bijvoorbeeld bij vraag B7 en B8: u heeft geen aangepaste zolen), dan kruist u **"niet van toepassing"** aan.*

C. MOEITE MET ACTIVITEITEN

Wilt u bij de volgende vragen alleen een antwoord geven, als dit antwoord met uw voet-klachten samenhangt; als dat niet het geval is, kruist u "niet van toepassing" aan.

Vraag:
Hoeveel moeite had u in de afgelopen week, als gevolg van uw voetklachten, om de volgende handelingen uit te voeren?

		Geen moeite	**enige moeite**	**nogal wat moeite**	**veel moeite**	**niet te in staat**	**niet van toepassing**
C1	Binnenshuis lopen?	❒	❒	❒	❒	❒	❒
C2	Buitenshuis lopen op oneffen terrein?	❒	❒	❒	❒	❒	❒
C3	500 meter of meer lopen?	❒	❒	❒	❒	❒	❒
C4	De trap **oplopen**?	❒	❒	❒	❒	❒	❒
C5	De trap **aflopen**?	❒	❒	❒	❒	❒	❒
C6	Op de tenen staan?	❒	❒	❒	❒	❒	❒
C7	Opstaan uit een stoel?	❒	❒	❒	❒	❒	❒
C8	Een stoeprand op- of afstappen?	❒	❒	❒	❒	❒	❒
C9	Snel lopen of rennen?	❒	❒	❒	❒	❒	❒

Let op: *Als èèn of meerdere situaties niet voorkwamen (bijvoorbeeld bij vraag C2 en C8: u kwam de afgelopen week helemaal niet buiten), dan kruist u* ***"niet van toepassing"*** *aan.*

<u>Einde van de vragenlijst</u>

CHAPTER TEXTBOOK EFORT 2014 “LESSER TOE DEFORMITIES”

Lesser Toe Deformities

Jan W. Louwerens and J. C. M. Schrier

Contents

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Abstract

Introduction The prevalence of lesser toe deformities among the general population is high. These individuals show symptoms including pain, malalignment, functional problems and problems wearing shoes. These problems are often encountered in general Orthopaedic practice.

This chapter gives an overview of the aetiology, anatomy and pathophysiology of biomechanically-induced toe problems. In this chapter management is focussed on the operative treatment.

Aetiology and Classification Footwear seems to be the most common cause of complaints involving the toes and the forefoot. The function of toes is compromised if the foot is limited by a shoe and furthermore the toes might be fixed in malposition and/or malalignment. It leads to structural changes, especially in narrow, too-small shoes.

Other influential factors are: genetics, hallux valgus, neuromuscular conditions and arthritis.

Hammer toe, Claw toe and Mallet Toe; Definitions The general definitions of claw toe and hammer toe have been confused. A mallet toe involves the distal interphalangeal (DIP) joint; the distal phalanx is flexed on the middle phalanx. A hammer toe deformity comprises flexion of the proximal interphalangeal (PIP) joint. A claw toe is defined as having a flexion deformity at the PIP and DIP joints and hyperextension at the MTP joint.

Anatomy and Biomechanics The lesser toes play a role in stabilizing the foot while standing, leading to stability/balance control. It is very important to realize that the function of the toes is intimately related to the function of the plantar aponeurosis. It helps to support the longitudinal arches of the foot and to hold the foot together. The metatarsophalangeal (MTP) joint is stabilized by the capsule, collateral ligaments, plantar aponeurosis, intrinsic and extrinsic musculature.

Pathophysiology Different mechanisms may play a role in the development of lesser toe deformities. On the one hand, imbalance of intrinsic and extrinsic foot muscles is regarded as the general underlying pathological process. Whether the muscle imbalance precedes the deformity or whether the deformity precedes the muscle imbalance is not always clear.

On the other hand, rupture of the plantar plate is regarded as a causative factor. This instability leads to extension at the MTP joint, with further progression of deformity and herniation of the metatarsal heads.

Diagnosis From a biomechanical point of view a relation between deformity, local swelling and/or local bony prominence on one side and the complaints on the other side is expected. The foot is examined in the relaxed state, on weight-bearing and whilst walking. Antero-posterior and lateral radiographs of the foot on weight-bearing are usually essential and in the vast majority of cases when it concerns lesser toe problems no further diagnostic measures are necessary.

Indications for Surgery The estimation of benefit of the operative procedure must be weighed against the results and possibilities of conservative treatment and against the risk of (post-) operative complications and the burden of post-operative recovery.

Surgical Treatment Several soft tissue and osseous procedure, with correction of deformities, are described.

Other Lesser Ray Pathology and Deformities In the case of a mallet toe the distal phalanx is flexed on the middle phalanx. A crossover toe usually describes the situation in which the second toe deviates dorsomedially in reference to both the hallux and third toe. The second toe crosses over the hallux.

An overlapping fifth toe deformity usually consists of dorsiflexion contracture at the MTP joint with also an adduction and external rotation component of the fifth toe

Complications Complications following different surgical procedures are described.

Keywords

Aetiology • Biomechanics • Classification • Claw toe • Complications • Crossover toe • Deformities • Diagnosis • Hammer toe • Lesser Toes • Mallet toe • Overlapping fifth toe • Pathophysiology • Rehabilitation • Surgical indications • Surgical Techniques

Introduction

Although the lesser toes, from a functional point of view, play a lesser role as compared with the first ray it is obvious that problems arising from the toes can be very troublesome and at times disabling. The incidence of hammer toe and claw toe deformities ranges from 2 % to 20 % [1, 2]. Deformities in general develop slowly and insidiously and their incidence increases with age, peaking in the sixth and seventh decades. Lesser toe deformities occur more commonly in women than in men [1, 2]. In a study regarding non-institutionalized people 65 years of age and older selected by a random sample from community registers ($n = 7{,}200$) it appeared that 20 % of the respondents had more than 4 weeks duration of non-traumatic foot complaints [3]. The main complaints were pain (60 %) and this involved malpositioning of the toes or toenail problems in 20 % of the cases. These complaints were clearly associated with limited mobility and poor perceived well-being. Such complaints are probably heavily underreported as many patients belief that foot trouble is an inescapable phenomenon of ageing [4].

This chapter offers an overview of the aetiology, anatomy and pathophysiology of biomechanically induced toe problems. The role of claw toe deformity as a cause of metatarsalgia in literature is underestimated. The pathophysiology of this mechanism and the operative treatment is described in detail. Clear understanding of this process is essential in the treatment of claw toe deformity whatever the cause of this condition. Toenail problems, neuropathic complaints, arthritic and skin problems are not discussed in this chapter.

Management is focussed on the operative treatment. Surgical procedures to the lesser toes are considered as simple operations. However, all foot surgeons experience that patients can return after foot reconstructive procedures and then complain about, for instance, one of the lesser toes being too long. It is estimated that just in the USA yearly more than 300,000 lesser toe operative procedures are performed. The outcome, in a minor to major degree, is disappointing in more than 16 % of the cases resulting in 50,000 unhappy toe patients a year [5, 47].

Aetiology and Classification

Aetiology

The reported incidence of hammer and claw toes ranges from 2 % to 20 % [2]. This deformity is most common in societies using western type shoes. It is estimated that 50 % of women older than 60 years will have some deformity of the toes. The incidence peaks in the sixth and seventh decade. These deformities occur more frequently in women than in men (4 5:1) [6].

There is a linear relationship with footwear, age and gender [7]. Footwear seems to be the most common cause of complaints involving the toes and the forefoot. The forefoot shape of shoes worn by people in most western countries is not shaped anatomically; this is especially the case in women s footwear. This may partly account for the difference in incidence between gender. It has been reported that 86 % of analysed women had shoes with incorrect size [8]. If not the cause, then at least it is the use of shoes that very often induces the foot complaints. The function of toes is compromised if the foot is limited by a shoe and furthermore the toes might be fixed in malposition and/or malalignment. It leads to structural changes, especially in narrow, too-small shoes. Restriction of the toes in a narrow shoe will lead to buckling. The plantar stabilizing structures (aponeurosis, intrinsic flexors, joint capsule) have been reported to be permanently stretched in some persons

Table 1 Aetiology of toe deformities-the cause of deformity is not always clear

Foot wear	
Genetics	Gender, cavus foot, club foot, (curly toe, digiti quinti varus)
Hallux valgus complex	Overload of adjacent lesser rays
Diabetes	Neuropathy
Trauma	Fracture, compartment syndrome of lower leg compartments [10]
Arthritis	Rheumatoid, gout, psoriatic, pyrophosphate deposits
Neuromuscular	Charcot-Marie-Tooth, Fried Reich s ataxia, cerebral palsy, cerebral stroke, myelodysplasia, multiple sclerosis, collagen deficiency disorders, Hansen s disease
Anatomy	Long second ray, hallux valgus, shape of middle phalanx
Others	Infection, iatrogenic

Fig. 1 Hammertoe deformity of the second and third toes

wearing higher-heeled shoes [9]. Over many years this stretching may lead to insufficiency of these plantar structures. Eventually this is described to result in dislocation of MTP joints and fixed deformity of the IP joints. It is obvious that footwear is only one of the multiple factors which may play a role in the development of lesser toe deformities. Factors involved are summarized in Table 1 and the most important patterns of pathophysiology are described in the paragraph in question.

Hammer Toe, Claw Toe and Mallet Toe; Definitions

The general definitions of claw toe and hammer toe have been confused. The literature shows little consensus regarding definitions of these deformities [11]. After evaluating commom definitions among Dutch Orthopaedic departments many variations were encountered [12]. Most consensus was found regarding the definition of a mallet toe. A mallet toe involves the distal interphalangeal (DIP) joint; the distal phalanx is flexed on the middle phalanx. Coughlin makes a distinction between a simple hammer toe and a complex hammer toe [1]. A simple hammer toe involves the proximal interphalangeal (PIP) joint; the middle and distal phalanges being flexed on the proximal phalanx (Fig. 1). A complex hammer toe typically involves one or two toes and consists of a flexion deformity of the PIP joint and hyperextension deformity of the MTP joints. A claw toe is defined as having a flexion deformity at the PIP and DIP joints and hyperextension at the MTP joint. Coughlin recognizes the overlap in the definitions of complex hammer toes and claw toes, but reserves the term claw toes for those situations in which, usually, all lesser toes are involved and often have an underlying neuromuscular disorder [1].

In the authors view it seems more practical to distinguish toe deformities on basis of the findings at the MTP joint. The importance of changes at this joint from a biomechanical point of view are explained in the following sections. As long as with the reversed-windlass mechanism, thus with the push-up test (Fig. 12), the toe straightens at the MTP joint, toes with a flexion deformity at the PIP joint are defined as hammer toes. As soon as a fixed hyperextension deformity becomes clear at the MTP joint, in this chapter, the toe is defined as a claw toe. Many deformities might start out as a mild hammer toe and gradually

Fig. 2 Clawing of the toes with flexion contracture of IP joints as sequela of acute lower leg compartment syndrome

evolve into a fixed claw toe. As this distinction can have clinical consequences the authors of this chapter feel there should be no difference in terminology whether it be in one ray or in more rays and whether the cause be a hallux valgus complex, rheumatoid arthritis or a neuromuscular disorder.

Unfortunately this definition also does not cover all deformities. Some conditions lead to the development of clawing of the toes in which all joints (MTP, PIP and DIP) become flexed. Typically this can be the case after trauma with acute lower leg compartment syndrome resulting in muscular shortening and contracture (Fig. 2). An identical deformity can be seen in patients with spasticity or other neurological disorders. It must be taken into account that such deformity can be both dynamic and static.

Anatomy and Biomechanics

The lesser toes play a role in stabilizing the foot while standing, leading to stability/balance control. They also play a role both through an active and through a passive mechanism during propulsion. The extrinsic and intrinsic muscles (the lumbricals, the interossei, the short flexors and extensors) around these joints have an active role in this process. It is very important to realize that the function of the toes is intimately related to the function of the plantar aponeurosis. This longitudinal fascia is attached proximally to the heel and distally to the plantar aspect of the toes. In the stance phase the fascia aponeurosis, through the reversed-windlass mechanism, passively pulls the toes downward herewith increasing contact with the floor (Fig. 3a). At the same time the longitudinal arch of the foot lowers and lengthens (thus the foot angle in Fig. 3b increases). Also, passively, in the push-off phase, when the toes are dorsiflexed at the metatarsophalangeal joints, the plantar aponeurosis is tightened, thereby shortening the foot and increasing the longitudinal foot arch (thus the foot angle decreases, Fig. 3b). Together with active contracture of muscles, the fascia, thus, enhances bracing of the foot for propulsion.

Plantar Aponeurosis

The plantar aponeurosis consists of a strong, thick central part and weaker medial and lateral portions [13]. It covers the whole length of the sole and consists of dense fibrous connective tissue. It helps to support the longitudinal arches of the foot and holding the foot together. It arises from the tuber calcanei and divides into five bands, enclosing the digital tendons. They are attached to the margins of the fibrous digital sheaths and to the sesamoids of the great toe. The plantar aponeurosis is connected by two strong fibrous bands, with the plantar joint capsule and the proximal phalanx [9]. The important role of the windlass mechanism and the reversed windlass mechanism has been discussed above.

Intrinsic and Extrinsic Muscles Attached to the Toes

An overview of the anatomical location of these muscles is given in Tables 2 and 3. Four muscular layers in the sole of the foot are distinguished in Table 3. They help maintaining the arches of the foot and thus play a supportive role as one stands

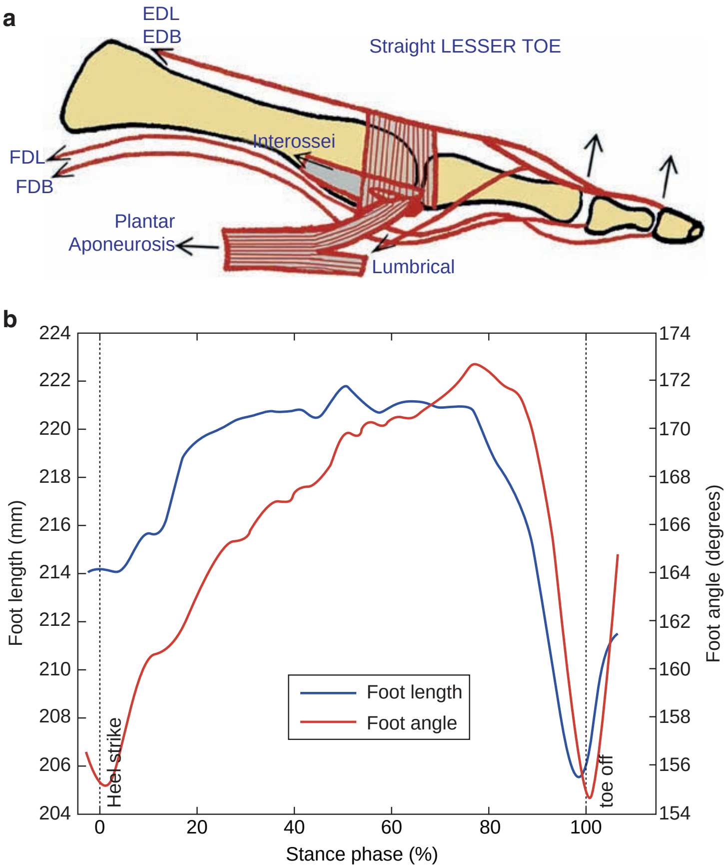

Fig. 3 (**a**) As the longitudinal arch of the foot lowers and lengthens in the stance phase the fascia aponeurosis, through the reversed windlass mechanism, passively pulls the toes downward herewith increasing contact with the floor. (**b**) Lengthening and shortening of the foot during the walking cycle. (with permission of Keijsers N. Sint Maartenskliniek Research, Nijmegen, NL)

Table 2 Muscles on the dorsum of the foot [13]

	Proximal attachment	Distal attachment
Extensor digitorum brevis	Anterior part of the dorsal surface of the calcaneus	Lateral edge of corresponding extensor digitorum longus digits 2 4
Extensor hallucis brevis	Anterior part of the dorsal surface of the calcaneus	Base of proximal phalanx of hallux
Extensor hallucis longus	Middle part of anterior fibula and interosseous membrane	Base of distal phalanx of hallux
Extensor digitorum longus	Lateral condyle of tibia and interosseous membrane	Middle and distal phalanges of digits 2 5

on uneven ground. The fine control of the individual toes is not important to most people, so the muscles in the sole of the foot are of little importance individually [13]. The plantar interossei adduct the digits; the dorsal interossei abduct the digits. The interossei maintain the integrity of the forefoot by approximating the bones during weight-bearing. The interossei also

Table 3 Muscles in the sole of the foot

	Proximal attachment	Distal attachment
First layer		
Abductor hallucis	Medial process of tuberosity of calcaneum, flexor retinaculum and plantar aponeurosis	Medial side of base of proximal phalanx of hallux
Flexor digitorum brevis	Medial process of tuberosity of calcaneum, plantar aponeurosis and intermuscular septa	Both sides of middle phalanges of digits 2 5
Abductor digit minimi	Medial and lateral process of tuberosity of calcaneum, plantar aponeurosis and intermuscular septa	Lateral side of base of proximal phalanx of fifth digit
Second layer		
Quadratus plantae	Medial surface and lateral margin of plantar surface of calcaneum	Posterolateral margin of tendon of flexor digitorum longus
Lumbricals	Tendons of flexor digitorum longus	Medial sides of bases of proximal phalanges of digits 2 5 and extensor expansions of tendons of extensor digitorum longus
Third layer		
Flexor hallucis brevis	Plantar surfaces of cuboid and lateral cuneiform bones	Both sides of base of proximal phalanx of hallux
Adductor hallucis	*Oblique head:* bases of metatarsals 2 4	Lateral side of base of proximal phalanx of hallux
	Transverse head: plantar ligaments of metatarsophalangeal joints	
Flexor digiti minimi brevis	Base of fifth metatarsal bone	Base of proximal phalanx of fifth digit
Fourth layer (deep)		
Plantar interossei (three muscles)	Base and medial sides of metatarsal bone 3 5	Medial sides of bases of proximal phalanges of digits 3 5
Dorsal interossei (four muscles)	Adjacent sides of metatarsal bones 1 5	1st: medial side of proximal phalanx of 2nd digit
		2nd 4th: lateral side of digits 2 4
Posterior compartment of leg (including popliteus and tibilias posterior)		
Flexor hallucis longus	Inferior two-thirds of posterior surface of fibula and interosseous membrane	Base of distal phalanx of hallux
Flexor digitorum longus	Medial part of posterior surface of tibia and by broad aponeurosis to fibula	Base of distal phalanges of digits 2 5

flex the toes at the MTP joints. The lumbricals flex proximal phalanges and extend middle and distal phalanges of the digits 2 5. Loss of their strength plays a role in development of toe deformities as there is decrease force to counteract dorsiflexion at the MTP joints and decrease force to counteract flexion at the IP joints (Figs. 4 6).

Metatarsophalangeal (MTP) Joints and Muscle Balance of the Toes

The fibrous capsules of the MTP joints are strengthened on each side by thick collateral ligaments. The plantar part of the capsule is greatly thickened to form the plantar ligament. This fibrocartilaginous plate is firmly attached to the

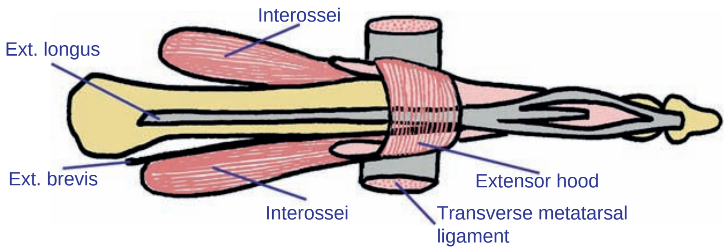

Fig. 4 Dorsal aspect including other attachments to the toe

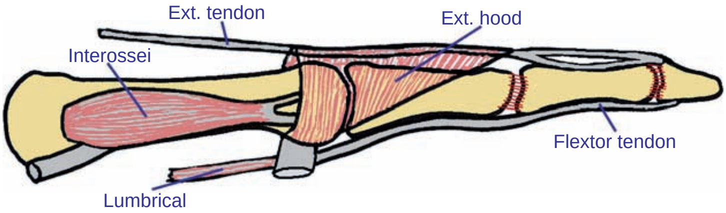

Fig. 5 Attachment of the flexor tendons to the toe

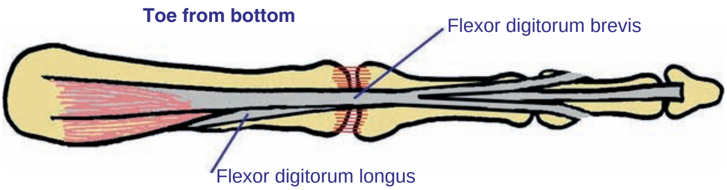

Fig. 6 Lateral aspect of attachments to the toe

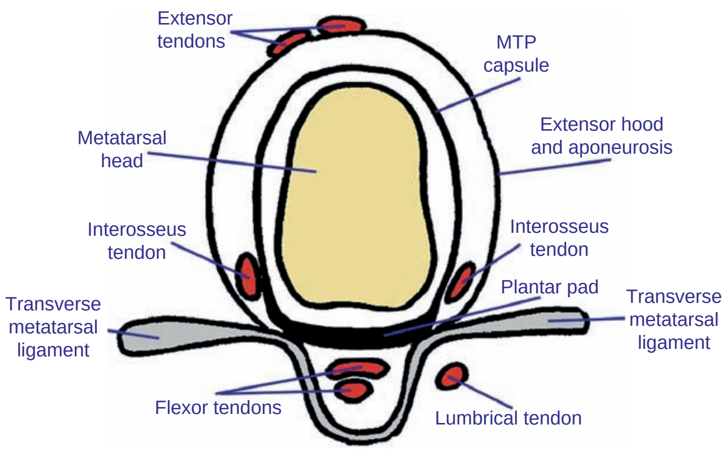

Fig. 7 Tendons of the toe in the coronal plane

proximal border of the phalanx and forms part of the socket for the head of the first metatarsal. The margins of the plantar ligament provide attachments to the fibrous flexor sheath, to slips of the plantar aponeurosis, and the deep transverse metatarsal ligaments (Fig. 7).

Normally there is a slight dorsiflexion (25°) position of the lesser toes in the MTP joint [9].

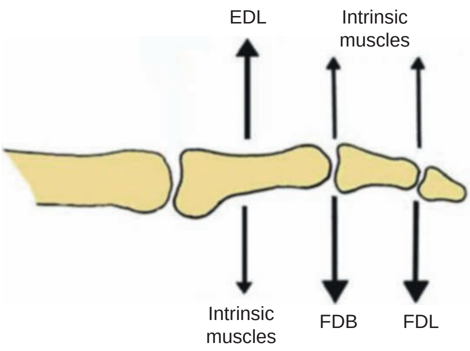

Fig. 8 Balance of forces around the toe

The position of the proximal phalanx at the MTP joint is subject to the antagonistic action of the extensors and intrinsic flexors (the lumbrical and plantar interosseous muscles). The joint is additionally stabilized by the plantar aponeurosis and the short flexor muscle [14]. The strong extension forces of the extensor digitorum longus (EDL) and extensor digitorum brevis (EDB) muscles at the MTP joint are balanced by interosseous and lumbrical muscles (intrinsics) and the flexor digitorum longus muscle (FDL). The EDL has an extensor action on the distal and proximal interphalangeal joints together with the intrinsics (Fig. 8).

Pathophysiology of Lesser Toe Deformities

It is not always clear why and how toe deformities develop. The aetiology of toe deformities has be discussed in the previous paragraph. In the present paragraph different mechanisms that may play a role in the development of hammer toe and/or claw toe deformity are described.

Imbalance/Synovitis

Imbalance of intrinsic and extrinsic foot muscles is regarded as the general pathological process, in the development of lesser toe deformities [9, 15]. In neurological disorders, absence of intrinsic function is usually the primary causal factor. When the intrinsics are weak, the unopposed action of the extensors is believed to cause hammer toe deformity [16]. Kwon et al. have so far been the only to quantify an increase of the ratio between extensor and flexor (intrinsic) muscle strength. They did so by comparing toe forces between healthy (without neuromuscular disorder) persons, with hammer toe deformity, with controls without hammer toe deformity. This supports the theory of muscular imbalance [16]. This increase of ratio was related to the angulation of the MTP joints (more dorsiflexed position) and to less dorsiflexion motion of the ankle joint and less eversion at the subtalar joint. In contrast a study from Bus et al., in patients with diabetes, did not confirm this relative increase of extensor force [2].

Whether the muscle imbalance precedes the deformity or whether the deformity precedes the muscle imbalance is not always clear. However, increase of dorsiflexion position of the MTP joint and decrease of intrinsic muscle force are related. Extension of the MTP joint causes shifting of the axis of the intrinsic musculature. This results in loss of plantar pull, with progression of extension in the MTP joint. When this happens and the FDL contracts, there is a greater contraction of the intrinsics, with loss of plantarflexion of the MTP joint. This leads to progression of extension deformity in the MTP joint. At the interphalangeal joints the stronger flexors overpower the intrinsics. Hyperextension at the MTP joint will lead to flexion deformity at the interphalangeal joints [17].

The increase of extensor force on the toes relatively to the force of the intrinsics can be due to decrease of intrinsic muscle strength as can be the case in patients with polyneuropathy. It is also attributed to relative overactivity of the extensors while they are compensating for loss of dorsiflexion strength of the tibialis anterior muscle, so called recruitment of the extensors (Fig. 9) [14]. Also tightening and shortening of the plantar flexor muscles, particularly the gastrocnemius muscle, probably plays a role leading to decrease of dorsiflexion range of motion at the ankle and results in overutilization of the EDL [14]. The above mentioned relation found between

Fig. 9 Recruitment of the long extensors of the hallux and the lesser toes

hammer toe formation, increase of MTP joint angle and decrease of dorsiflexion at the ankle joint seems to substantiate this theory [16].

The increase of MTP joint angle has been explained to be a possible initiating factor in the development of hammer toe deformity. It may be the cause of muscle imbalance around these joints. This seems to be the case in patients with hallux valgus complex particularly at the second MTP joint. Whether the dorsiflexion position is caused through malalignment (valgus position of the hallux, shoewear) or through synovitis, or both, is not always clear. In patients with polyarthritis particularly when multiple or all lesser MTP joints are involved it seems clear that the residual synovitis is the cause of the increased dorsiflexion position.

Plantar Plate/Fat Pad

The plantar plate is an important structure in stabilizing the MTP joint [18, 19]. It is regarded as a thickening of the capsule, below the metatarsal head [20]. It is firmly attached to the base of the proximal phalanx and weak attachment to the metatarsal neck. During push-off the plate is affected by extension stress, which increases the risk of rupture with resulting instability [21]. Stainsby [20] describes a strong ligamentous band in the forefoot, consisting of connections between the plantar plates and the transverse metatarsal ligaments, forming a continuum (tie bar). This controls the splay of the forefoot. The deeper layer of the plantar fascia, controlling the longitudinal arch, is also centred on the plantar plates.

Rupture of the plantar plate can cause instability of the MTP joint. In case of this instability, possibly in conjunction with synovitis of the joint, the proximal phalanx shifts dorsally in relation to the MT head. This shift can often be demonstrated during physical examination through the so-called Lachman manoeuvre of the affected MTP joint. The relative dorsiflexed position may, in turn, initiate further deformity of the toe.

The plantar fat pad is situated beneath the metatarsal heads and consists of thickened subcutaneous tissue [20]. It serves as a protective cushion to diminish the stresses [17]. Atrophy of the plantar fat pad is described to play a role in the process of lesser toe deformities [22]. However, the relationship between fat pad atrophy and metatarsalgia is disputed [23]. It has become increasingly clear that most often the relative prominence of the MT heads is not to be attributed to fat pad atrophy, but to dislocation of the fat pad and other soft tissues as a result of deformity [24, 25]. Hyperextension deformity at the MTP joint will gradually lead to distal and dorsal dislocation of the plantar plate in relation to the MT head (Fig. 10). Eventually the proximal attachment of the plantar plate, at the metatarsal neck, might rupture and/or split, followed by dislocation of the MTP joint and with relative depression of the MT head. The MT head as we see in patients with rheumatoid arthritis eventually can herniate through the joint capsule and become tethered in a plantar position.

Bus et al. have shown that the toe angle in patients with diabetes has a positive correlation with plantar pressure [26]. They also demonstrated the displacement of the plantar fat pad as described above in relation to increase toe angle (toe deformity) using MRI imaging. Displacement of this important cushion causes relative prominence (deepening) of the MT head and relative decrease of the weightbearing surface and thus increase of pressure.

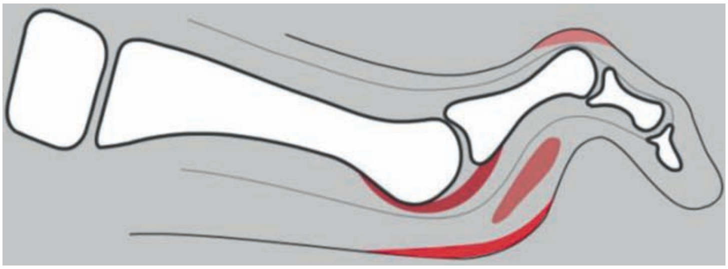

Fig. 10 Hyperextension deformity at the MTP joint will gradually lead to distal and dorsal dislocation of the plantar plate in relation to the MT head

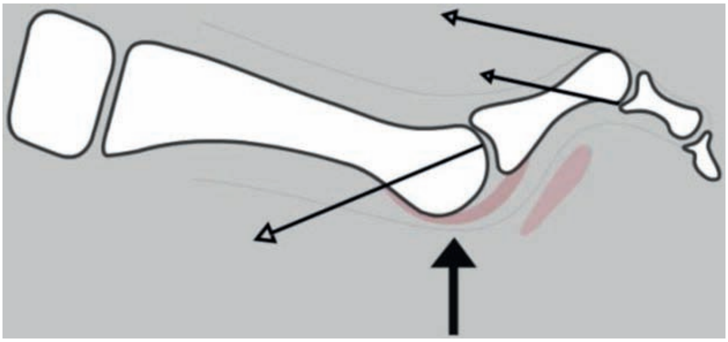

Fig. 11 Increase (in stance) of plantar pressure on the MT head resulting from pull by the extensor and flexor tendons in a case of claw toe deformity

Additional biomechanical factors subsequently play a role. The same forces applied by the tendons that lock the MTP joints in extension and the toes in flexion also result in a plantarward force on the metatarsal heads (Fig. 11). This results in increased pressure on the soft-tissues underneath the metatarsal heads.

Diagnosis

Patients might experience: pain while walking, pain wearing shoes, balance problems and limited walking distance. From a biomechanical point of view a relation between deformity, local swelling and/or local bony prominence on one side and the complaints on the other side of the toes is expected. The localization and the type of the pain should match with an area of increased pressure resulting in the development of callosity, hard corn or soft corn. Situations with increased plantar keratosis or plantar pressure commonly provoke more pain during bare foot weight-bearing and walking, while pressure sores on the dorsal aspect of the toes and between the toes typically are painful when wearing shoes. Pressure points at the top of the toes are commonly related with mallet toe deformity or clawing of the toes.

The foot is examined in the relaxed state, on weight-bearing and whilst walking. As noted previously patients with spasticity may present with dynamic deformities. The toes may be straight and flexible in the relaxed state and the mechanism of increased pressure causing pain and cramp may be exhibited only on weight-bearing and/or walking. The general appearance of the foot and visible deformities are described. The position of the joints of each toe should be observed and documented. The position, range of motion, flexibility and stability (Fig. 12) of each joint should be regarded.

At the MTP joint a possible subluxation or dislocation of this joint and the position of the fat

Fig. 12 (**a**) Extension of the MTP joints non-weight-bearing. (**b**) Stretching to neutral with push-up. (**c**) Further plantarflexion in MP joints is possible. (**d**) Push-up test

pad should be examined. Pain on the dorsal aspect of these joints, particularly in combination with swelling of one or more of these joints, is a sign of inflammation, synovitis, or arthritis. Movement of the joints provokes typical pain. Pain at the plantar aspect of the MT head, particularly in conjunction with localized callus formation, without pain at movement of the joint and without dorsal pain is indicative for biomechanically induced metatarsalgia. Not only should metatarsalgia be distinguished from intra-articular disorders, it should also be distinguished from Morton s neuralgia, neuropathic complaints, skin disorders (for instance verruca) and disorders within the webspace (for instance a ganglion).

Particularly in patients with sensory neuropathy increase of pressure is associated with hyper keratosis and soft tissue necrosis and secondary infection are common problems in these patients. The occurrence of bone tumours in the toes is rare (Fig. 13). Finally, also the vascular status should always be regarded.

Antero-posterior and lateral radiographs of the foot on weight-bearing are usually essential and in the vast majority of cases when it concerns lesser toe problems no further diagnostic measures are necessary. The role of MRI, CT scanning, ultra-sonography and bone scanning most often concerns the diagnosis of forefoot deformities which are not the subject of this chapter.

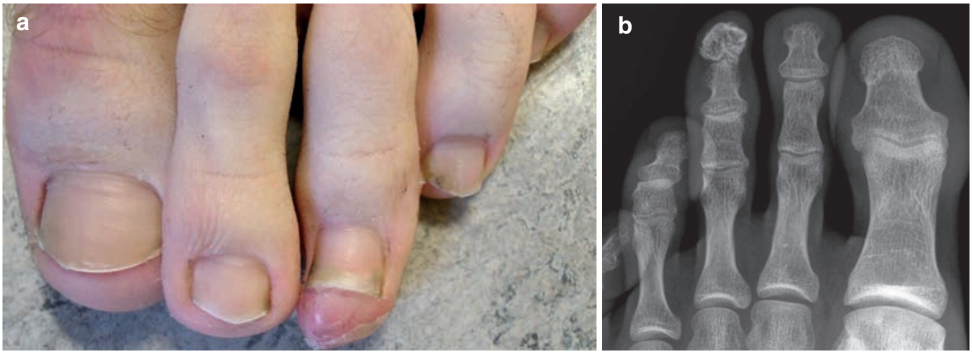

Fig. 13 (**a**) Enchondroma distal phalanx 3rd toe. (**b**) Radiographic appearance

Indications for Surgery

Changes to the forefoot, midfoot, hindfoot and leg are often related to one and other and multiple joint problems can be involved at the same time. In order to make clinical decisions the problems concerning the foot and ankle must be evaluated as a whole and advice to the patient is individualized, depending on general health aspects, involvement of other joints, age, patient expectation, social aspects, and the such. The choice for operative treatment depends on the amount of pain and disability and limitations of activity. The estimation of benefit of the operative procedure must be weighed against the results and possibilities of conservative treatment and against the risk of (post-) operative complications and the burden of post-operative recovery.

Operative Techniques- Claw Toe and Hammer Toe Deformity

The 'Standing Position'

Throughout this paragraph the term standing position (SP) refers to the situation in which the surgeon places the foot in a position as if it is bearing weight. The ankle and the whole hindfoot are moved in a normal as if weight-bearing neutral position by applying pressure under the forefoot at the proximal aspect of the metatarsal heads as performed with the push-up test (Fig. 12). This manoeuvre induces a reversed-windlass mechanism of the plantar aponeurosis and through this mechanism the toes are straightened and the MTPJ are stabilized. With this manoeuvre the acquired alignment of the toes at surgery can be inspected in an as much normal situation as possible. In this SP one can judge the tension on the toes resulting from shortened extensors, flexors or other contractures.

PIP Resection

This technique is applied to correct a fixed flexion deformity at the PIP joint or for treatment of an otherwise affected PIP joint (Fig. 14).

Either a dorsal longitudinal incision is used or a dorsal transverse incision. The advantage of the longitudinal approach is that the incision can easily be extended proximally and it provides maximal exposure. With the straight dorsal longitudinal approach, after the skin incision, the incision is directly deepened in the same line to the bone from the base of the middle phalanx to the proximal phalanx dividing the extensor tendon and also the joint capsule in the length through the centre line. Hohmann retractors are shifted over the bone under the tendon and driven round the phalanx just proximal to the joint on

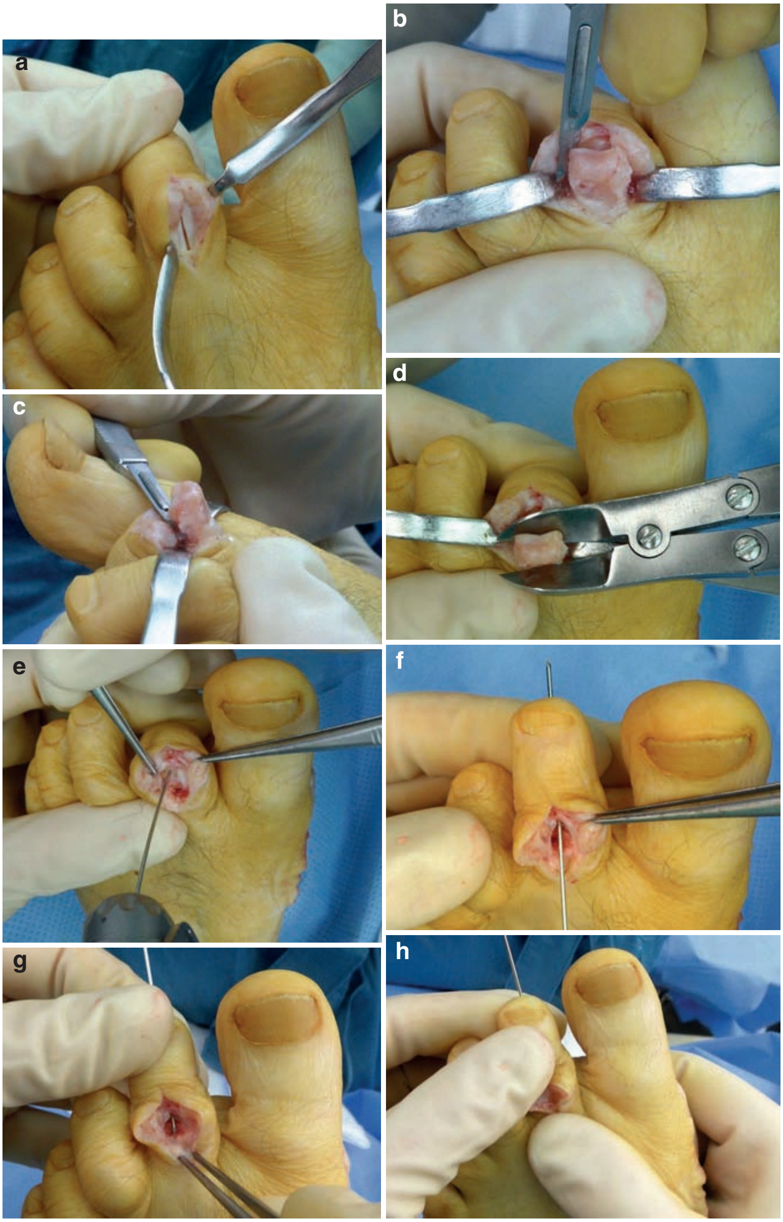

Fig. 14 Steps during PIP resection arthroplasty. (**a**) Dorsal median incision through the extensor tendons. (**b**) Cutting the collateral ligaments. (**c**) Releasing all the soft tissues from the condyle. (**d**) Excision of the condyle with bone cutter. (**e**) Introducing a 1.0 mm K-wire centrally into the base of the middle phalanx. (**f**) After drilling the K-wire through the distal part of the toe. (**g**) Introducing the K-wire centrally in the proximal phalanx. (**h**) The K-wire is drilled through the proximal phalanx and across the MTP joint

both sides. The joint is hereafter exposed by maximally opening the wound with the Hohmann retractors and at the same time flexing the joint. The capsule and collateral ligaments are stretched and can now quite easily be severed further exposing the condyles.

In case of the transverse incision, callus is removed through excision of an oval piece of the skin and subcutaneous tissue in one layer. An additional advantage might be that in closing this wound the toe is more or less pulled from a flexed to a straightened position. Most often the incision is directly deepened and the joint is directly opened by excision of the extensor and capsule of the PIPJ in the same line as the skin incision. One can also split the extensor tendon in the length over the PIPJ and proceed as if a dorsal longitudinal approach is used. However, one should realize that this oval incision is relatively short in comparison with the longitudinal approach. The PIPJ is maximally flexed and at both sides the condyles are freed by severing the collateral ligaments and capsular attachments and hereafter a Hohmann retractor is placed on both sides around the condyles of the basal phalanx.

Now that the distal part of the basal phalanx is free of all soft tissue attachments this part is resected using either a bone cutter or an oscillating saw. Usually resection of approximately 1 cm. of bone is enough and the cut is most often at the border between the metaphyseal and diaphyseal bone. The use of an oscillating saw prevents fracture of the phalangeal bone which easily occurs as soon as the cut is made more diaphyseal and in case of thin osteoporotic cortical bone (rheumatoids).

The foot is now straightened and placed in the SP. In this position one now judges if the toe can easily be straightened without bony contact between the cut surface of the basal phalanx and the articular surface of the middle phalanx. In case of tension and persistent malalignment some more bone can be resected. In the SP it is also determined if the basal phalanx is well aligned at the level of the MTPJ without too much extension due to extension contracture of the MTPJ and/or contracture of the extensor tendon(s). If this proves to be the case then further surgery might be indicated (See Claw Toe Correction section). In case of persistent flexion due to contracture of the flexor tendons, these tendons might need to be addressed (See Claw Toe Correction section).

At this stage a choice is made whether to fix the alignment or to trust on post-operative dressings. In case of an isolated procedure the toe can be easily splinted to adjacent toes, but in case of multiple toe corrections and in case the toe has a persistent tendency towards some malalignment or in case of a redo, K-wire fixation seems advisable.

A 1.0 1.25 mm K-wire is drilled through the centre of the articular surface of the middle phalanx retrograde through this phalanx and the distal phalanx, holding the DIP joint in neutral position, exiting centrally at the apex of the toe. Hereafter, the K-wire is drilled forwards through the basal phalanx as centrally as possible. With the foot in SP and the MTPJ held in neutral position (slight extension, equal angle as the adjacent normal MTP joints) the K-wire can be drilled across the MTPJ into the metatarsal bone. Herewith one is assured that also the MTPJ will remain in line for a longer period, which can be beneficial to secure the total alignment.

The wound is now closed. Particularly in case of the use of a transverse incision the extensor tendon is sutured. This can be done suturing the tendon together with the skin or suturing in two separate layers.

A gauze dressing with little to no compression is applied after surgery (Fig. 15). This dressing can be changed after 2 days or left until the sutures are removed. The patient is permitted to ambulate using a post-operative shoe with weight-bearing on the heel. The sutures are removed after 14 days. The K-wires are removed after 4 weeks. Further taping of the toe(s) is applied in case there is any tendency towards malalignment.

PIP Fusion

The approach is identical to that of the PIP resection arthroplasty. As the goal is now to achieve a bony fusion, in general, less bone is removed from the distal part of the basal phalanx.

Fig. 15 Wound dressing after surgery

The articular surface of the middle phalanx is also resected. Preferably the cut surfaces on both sides are made at the level of metaphyseal cancellous bone with its optimal bone healing properties. Of course the amount of bone resected depends on the amount of deformity. The more deformity, the more bone needs to be removed in order to acquire realignment. Removal of bone is performed with an oscillating saw in order to have precise control regarding the amount of bone removed and to acquire nice flat surfaces providing optimal bony contact.

The technique of K-wire fixation starts as described for PIP resection, however, at the moment the K-wire is drilled into the basal phalanx the cut surfaces should be compressed to assure good bony contact.

Post-operative radiographs are obtained at 6 weeks at which time the arthrodesis is usually sufficiently healed to advice a gradual return to walking without the postoperative shoe. Further taping of the toe(s) is applied in case there is tendency towards malalignment or delayed union.

Claw Toe Correction

The clinical implications of extension contracture at the MTP joint have been explained previously. For this reason it is generally advised to address this contracture when correcting a toe deformity. When pre-operatively it is not obvious that this joint is involved one can start with correcting the deformity of the PIP joint and evaluate the position of the toe hereafter in the SP. Through a dorsal longitudinal approach the incision can easily be lengthened in order to release the MTP joint when needed. It should be noted that by removing the PIP joint only and leaving the extension contracture unaddressed the result of surgery might be agreeable as most often the primary complaint is pain at the dorsal aspect of the PIP joint and that problem might already be solved. Through shortening of the toe the pull by the tendons might be adequately diminished and the bony prominence has been removed. However, from a practical point of view there is an increased risk for recurrent deformity, hyperextension of the toe (particularly if a PIP fusion has been performed without adequately neutralizing the force of the extensor tendons) and metatarsalgia may persist as the position of soft tissues might remain unfavourable.

The PIP joint and MTP joint are exposed through a dorsal longitudinal incision. When multiple MTP joints are involved a separate incision for each ray is feasible (Fig. 16).

The steps during claw toe correction are illustrated in Fig. 17. The incision is deepened to the extensor tendon and tissue in the intermetatarsal space is left undisturbed. The capsule of the MTP joint is exposed. One can start with a dorsal capsulotomy as a dorsal release, but most commonly there is shortening of the extensors. The short extensor tendon is divided proximally to the MTP joint and, hereafter, releasing the tendon in distal direction the dorsal base of the proximal phalanx will be located. At this level the long extensor tendon is subsequently divided. Before closure ensure that the short extensor tendon still attached to the basal phalanx bridges the gap between the basal phalanx and the severed long extensor tendon. An alternative is to perform a z-lengthening of these tendons. At this stage evaluate if the toe is sufficiently corrected in the SP (Fig. 12).

In case of dorsal subluxation or dislocation of the joint the following step is to perform further capsulotomy, synovectomy (in case of hypertrophic synovitis of the joint) and section of the

Fig. 16 (**a**) Dorsal incisions in order to address each ray separately. (**b**) After closure of the wounds

collateral ligaments. Hereafter, with some traction and plantarflexion to the toe the subluxed or dislocated MTP joints is further released. In case of dislocation with shortening patience is needed to carefully, with a sharp knife, release the soft tissues around the dorsal aspect of the metatarsal head manoeuvring underneath the dislocated phalanx. In dislocated cases one might encounter the flexor tendon located at the level of the MT head. This tendon is then usually divided. Before reducing the dislocation, traction is decreased by shortening the toe at the level of the PIP joints through resection of the distal part of the proximal phalanx. After sufficient release a curved elevator or dissector is moved around the MT head in a distal plantar direction without damaging the cartilage and after that moving from side to side also the sides of the MT head are fully released. This is to free adhesions and contractures, on the plantar aspect of the MT head. Hereafter, the MTP joints are easily reduced and the plantar fat pads move back under the MT heads, which is the goal of this procedure.

At this stage when too much pressure and tension at the MTP joint is still encountered one can further shorten the ray by removing a few millimetres more phalangeal bone at the PIP level or through shortening of the metatarsal bone. If in SP the toes are flexed due to shortened flexor tendons these tendons are divided at the level of the resected PIP joint. Another solution is to perform a flexor to extensor transfer as will be described later.

1.0 mm K-wires are now introduced at the PIP joint and driven into a distal direction through the middle and distal phalanges. The K-wire is pulled through and then drilled in proximal direction through the proximal phalanx until it is at the level of the cartilage at the base of the proximal phalanx. Now the foot is placed in the SP. At the same time the MTP joint is reduced and the position is secured with some pressure by the thumb on the base of the proximal phalanx securing optimal alignment. The MTP joint should be in slight plantar flexion position. While controlling the reduction and keeping the toe nicely aligned the K-wire is further advanced proximally into the metatarsal bone. Finally the extensor tendons are approximated, suture of the extensor tendon is optional.

After re-alignment of all toes involved the tourniquet is released and the return of circulation to the toes is observed. After correction of severe deformity, very often, initially there is very slow capillary refill for up to 5 min which can be due to constriction or to pull on the vessels as a result of lengthening. If the circulation remains endangered in the hours following surgery (do not elevate the foot), but after adjusting the K-wire, if there is no improvement in circulation, then the wire should be removed. The wounds are closed approximating the subcutaneous skin layer with vicryl 4 0 sutures and the skin with 4 0 nylon sutures.

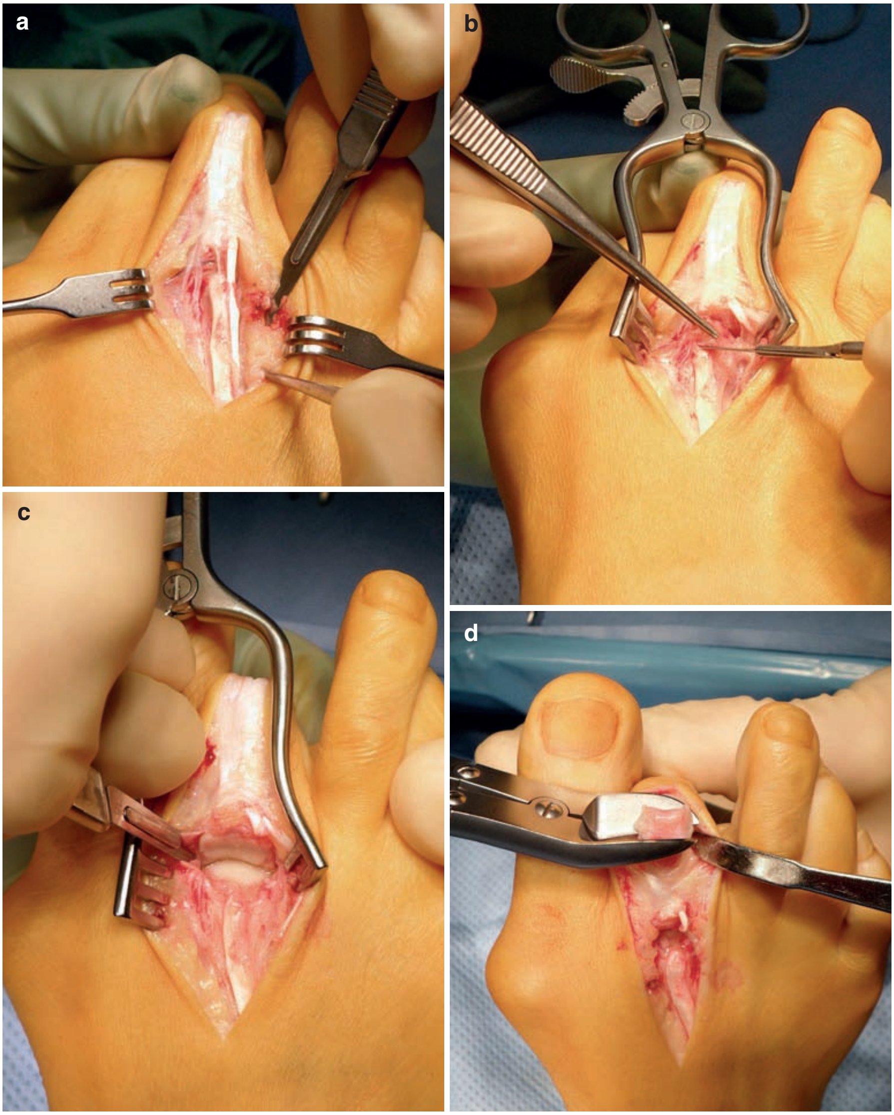

Fig. 17 (continued)

A gauze dressing with little to no compression is applied after surgery and changed after 2 days or left for 2 weeks. The patient is permitted to ambulate using a post-operative shoe with weight-bearing on the heel. The sutures are removed after 14 days. The K-wires are removed after 4 weeks and usually 6 weeks when combined with first ray bony procedure. The goal of a longer immobilization is to achieve healing and probably fibrosis of all plantar structures and other soft tissues to achieve a permanent alignment of the MTP joint. After removal of the K-wires the patients are instructed to passively mobilize the MTP joints, fixing the toe as a whole and dorsiflexing and plantarflexing at the joint. Further taping of the toe(s) is applied in case there is persistent tendency towards malalignment. Occasionally patients are referred to the physiotherapist, actually this is becoming more and more a standard.

Flexor-to-Extensor Transfer

After the first publications of the Girdlestone-Taylor transfer many tendon transfer procedures have been described in the literature, most reporting reasonable results [14, 16, 17, 21 27].

Fig. 17 (continued)

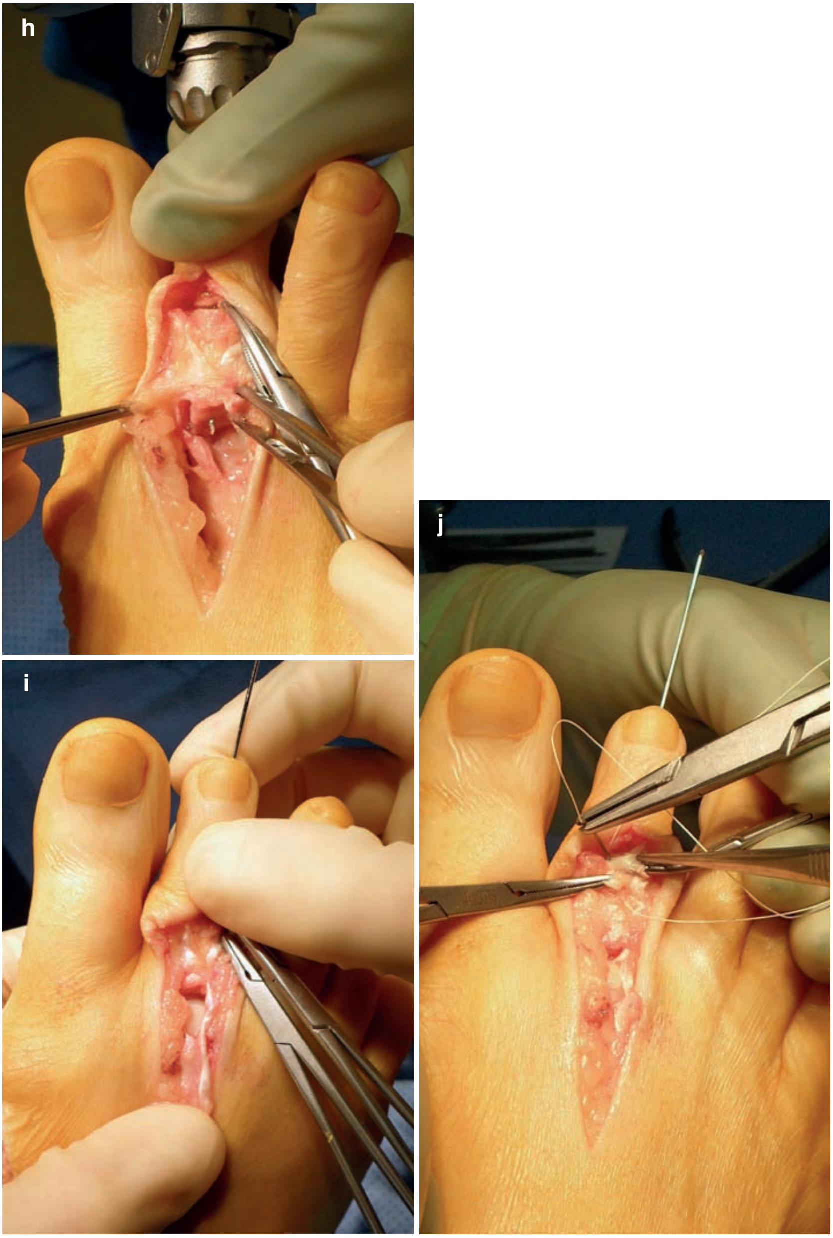

Fig. 17 Steps during surgery illustrating claw toe correction. (**a**) Lengthening of the extensor tendons. (**b**) Dorsal excision of capsule and synovitis. (**c**) Dislocated MTP joint. (**d**) PIP resection. (**e**) Release of the MTP joint with raspatorium. (**f**) Easy reduction is possible. (**g**) Introducing a 1.0mm K-wire through the distal part of the toe. (**h**) K-wire drilled in proximal direction through the proximal phalanx and enters the joint. (**i**) After retracting the K-wire, the joint is reduced in to an anatomical position with the foot in SP. Then the K-wire is drilled across the joint and into the MT bone. (**j**) Suture of extensor: in this case a flexor to extensor transfer was performed also. Closure follows

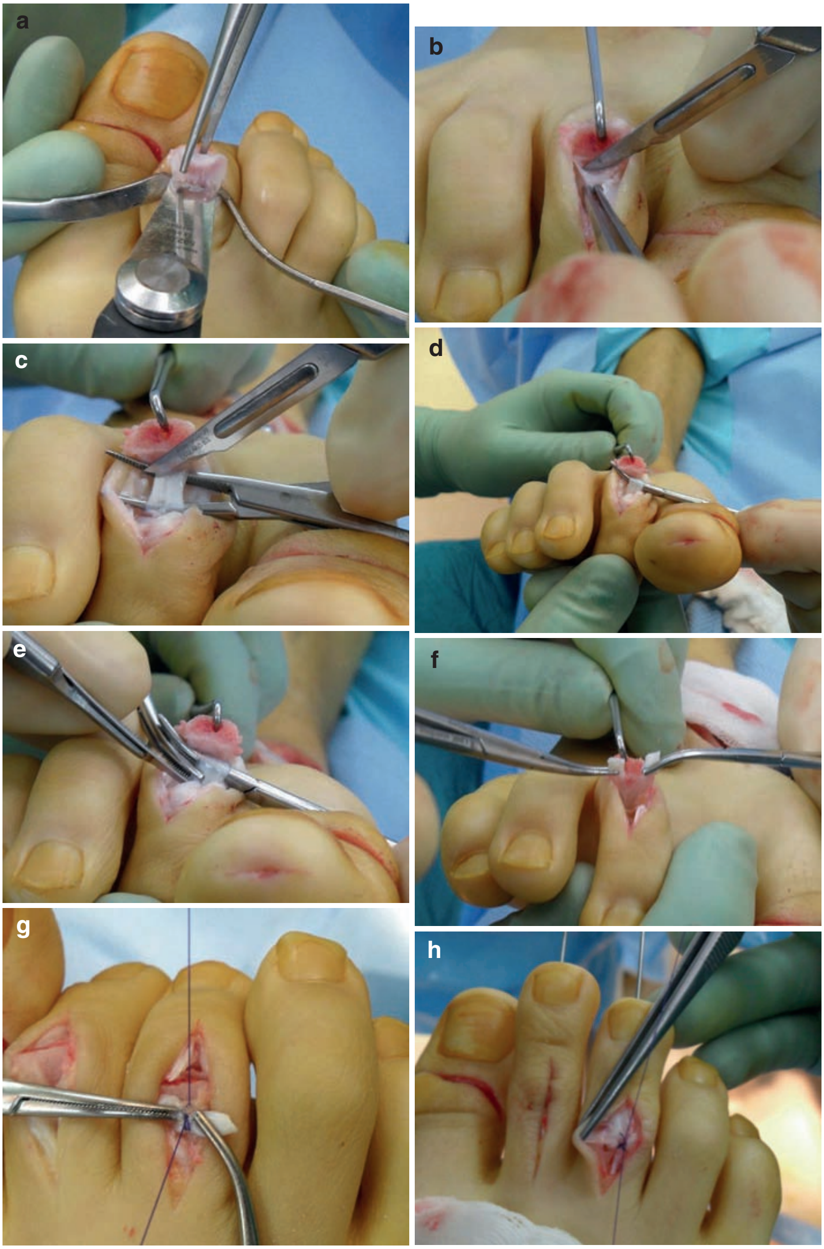

Fig. 18 Steps in flexor-to-extensor tendon transfer. (**a**) Resection of the condyles of the proximal phalanx as in PIP resection. (**b**) Excision of the plantar plate in order to expose the flexor tendons. (**c**) Cutting of the short flexor tendon. (**d**) Exposure of the long flexor tendon. (**e**) Before cutting the long flexor as distally as possible a clamp is placed on the tendon proximally. (**f**) Splitting of the tendon into two tails. (**g**) These are sutured on to each other on the dorsal aspect of the proximal phalanx with the MTP joint in correct position. (**h**) The extensor hood is sutured to the transferred flexor after K-wire fixation

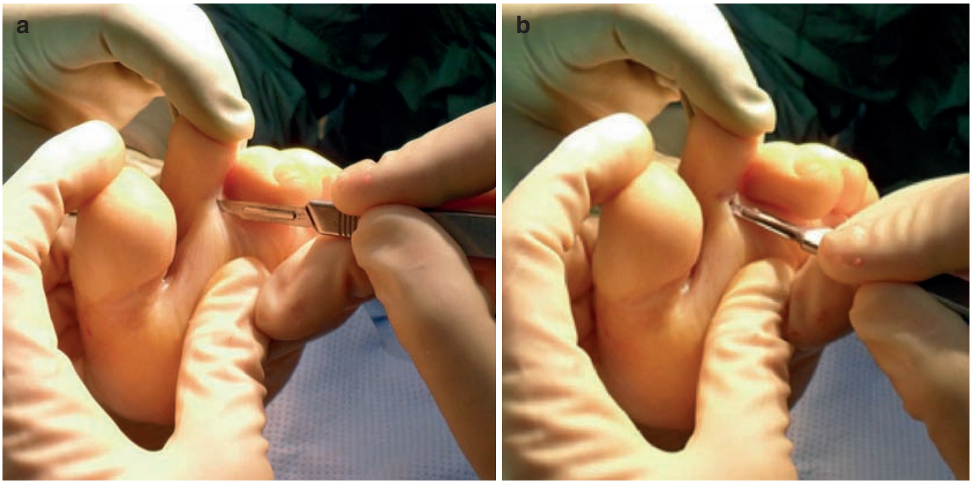

Fig. 19 (**a**) First the knife is directed longitudinally towards the basal phalanx. Hereafter the knife is turned 90 degrees. (**b**) Keeping the knife within the borders of the phalanx the tip of the knife is moved along the bone from one side to the other while tension is applied to the flexor of the toe

In general the tendon of the long flexor of the toe (FDL) is transferred towards the dorsal aspect of the toe at the distal level of the basal phalanx attaching the FDL tendon slips to each other and/or the conjoined extensors (Fig. 18). The transferred FDL hereafter works as an intrinsic muscle, flexing the toe at the MTP joint without flexing the toe itself. This procedure is also advocated to stabilize the MTP joint counteracting extension force and dorsal subluxation. Most often the short flexor (FDB) is left in situ, but in severe flexion deformity the tendon of FDB commonly is severed as well.

The indications to perform a flexor to extensor transfer are thus not only the flexible toe deformity, but this transfer can also be indicated in patients with neuromuscular toe deformities as discussed in the following and is used for stabilizing the MTP joint as mentioned above.

In our practice this procedure is most commonly applied in conjunction with correction of fixed claw toe deformity in patients with neuromuscular disorders, typically the younger Charcot-Marie-Tooth patients. Thus the transfer is combined with claw toe correction as described above in which a PIP resection is performed. After removal of the PIP joint the transfer of FDL to the basal phalanx is a relative easy procedure. The plantar plate at the PIP joint is partly removed and the flexor tendons are found directly plantar to this plate. The first layers of tendons are the slips of FDB (Fig. 20). The more pronounced the flexion deformity the more these slips are cut. The FDL, located plantar to FDB, is fixed with a small mosquito clamp and is tensioned flexing the toe. The tendon is now cut distally under the middle phalanx retrieving as much length as possible. It is advisable to have a mosquito clamp attached to the FDL because if the FDL is loosened the tendon quickly retracts proximally. Now the FDL is split in it s raphe into two tails. These tails are passed around the distal end of the basal phalanx delivering a tail on each side and sutured with the toe in correct position. The correct position and the K-wire fixation is as described for claw toe correction. For stabilization of the MTP joint the limbs of FDL are usually positioned more proximally around the base of the basal phalanx functioning as tenodesis rather than as flexor. After- treatment is as after claw toe correction.

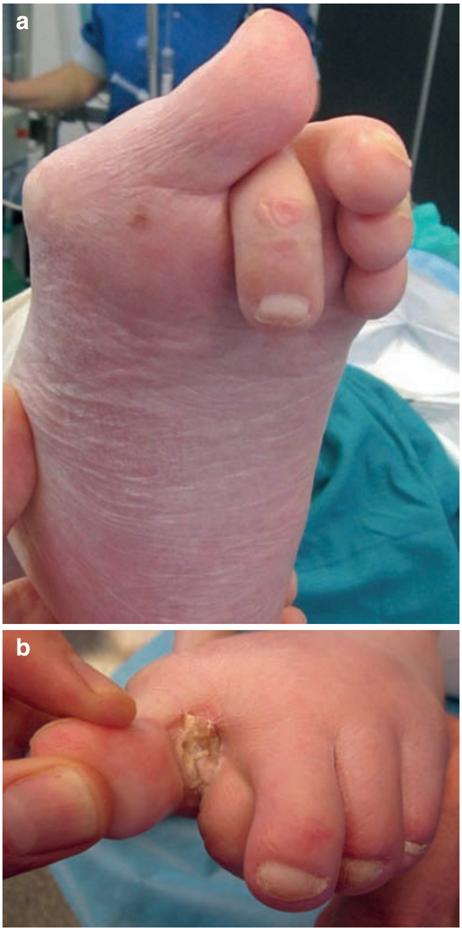

Fig. 20 (**a**) Rigid spastic flexion deformity causing pain on weight-bearing. Good indication for toe amputation. (**b**) Same patient with soft corn caused by severe pressure on phalangeal bone

Extensor Transfer

Patients with neuromuscular muscular imbalance commonly present with claw toe deformity. The pathophysiology has been described previously. The extensors of the toes are often recruited in order to enhance dorsiflexion of the foot. In these patients transfer of the long extensor of the toes (EDL) is to be considered. This is usually combined with transfer of the long extensor of the hallux as in modified Jones procedures. The EDL tendon can be transferred, for instance, to the lateral aspect of the foot (sutured to the peroneus tertius tendon, PT) or to the dorsum of the foot (sutured to the Tibialis anterior tendon). It is not always clear to which amount such a transferred tendon becomes an active evertor or extensor of the foot, but it in any case has a tenodesis effect and the deforming force on the toes is neutralized.

As we are talking about patients with claw toe deformity it is clear that the EDB is severed also. When the EDL tendons are cut proximally (region of PT) and the EDB tendons at the level of the MTP joints then the distal loose limbs of EDL can be transferred to the proximal limbs of EDB. In younger patients this procedure can be combined with flexor-extensor transfer of the toes as described above.

Percutaneous Tenotomy of the Extensors and/or Flexors- Minimally-Invasive Surgery (MIS)

In older patients with poorer skin properties and in patients with longstanding very severe deformity in our practice both the extensors and if necessary also the flexors are simply severed through shorter incisions or percutaneous, with or without MTP release and PIP resection (Fig. 19). Decreasing morbidity and less risk of complications can be reason to decide for this, but also decrease of tourniquet/surgery time as claw toe correction is very often only a minor part of extensive reconstructive surgery involving both hindfoot and forefoot.

One should always consider the effect of cutting these tendons on the muscle balance around the toes. Cutting the agonists, while the antagonists are still quite powerful can result in postoperative deformity. In the case illustrated in Fig. 2 (fixed flexion deformity at the PIP joints and flexed but flexible DIP joints) correction of the toes was achieved through PIP resection and tenotomy of the flexors. There is no reason to assume that the extensor will pull the toes in hyperextension afterwards. However, for instance, after lengthening or severing the extensors in many patients with claw toes it is quite likely that the flexors will later again flex the toes when the flexors are not addressed. Although such surgery from a functional point of view might not seem preferable it in practice gives good results, because the end goal, being an aligned toe with proper soft tissues plantar to the MT heads, is achieved. There has, never, or for a very long time not been, a normal function of the toes, after all.

Treatment of toe deformities by extensor tenotomy without flexor tenotomy has been reported to be responsible for the poor outcomes with percutaneous extensor tenotomy [27]. Surgeons performing percutaneous surgical procedures consider that treatment of these deformities by extensor tenotomy should also perform tenotomy of the flexors to prevent recurrence. It is considered that the intrinsic muscles will provide sufficient force for the toes to press on the floor in the final phase of stance. Using thin scalpel blades and straight burrs rigid deformities can be further addressed through percutaneous capsulotomy and by performing compensating phalangeal osteotomies or partial diaphysectomy [27].

Amputation of a Toe

Amputation has been described for severe deformity [28] (Fig. 20a). In elderly or patients with a higher risk for complications amputation might be a practical and rewarding solution. Removing the second toe does not solve the underlying cause of the deformity and progression of hallux valgus is to be expected. Removing any toe results in loss of the buttress effect of this toe in relation to the adjacent toes.

Osteotomy of the Phalangeal Bones

An excessively long toe, and most often this concerns the second toe, which is otherwise nicely aligned can be shortened through diaphysectomy [18]. When the toe has developed a fixed deformity at one of the IP joints shortening can be achieved through IP arthroplasty. In case of varus or valgus malalignement of the bones of the toe or after mal-union corrective wedge osteotomy can be applied (Fig. 21). First the soft tissues should be addressed and in our opinion such osteotomy should typically be considered in case of true bony malalignement.

Post-Operative Care and Rehabilitation

A gauze compression dressing is applied after surgery (Fig. 15). Gauzes are placed between all toes and cover the wounds. The whole foot and ankle is wrapped in a neutral position. The foot is elevated and rested as much as possible during the first days. As soon as normal sensation has recurred to the foot patients are permitted to ambulate in a post-operative shoe with weight-bearing on the heel. Unless the foot becomes symptomatic or the dressing fails the dressing is changed after 2 weeks. Skin sutures are removed after 2 weeks. K-wires are removed after 4 weeks when lesser toe surgery only has been performed. In case of additional surgery of the first ray or after bony procedures in general the K-wires are removed 6 weeks following surgery and at the same time the use of the post-operative shoe is stopped. Passive range-of-motion exercises are thus initiated either 4 weeks or 6 weeks after surgery. Application of tape, night splint or orthotics is individualized.

Other Lesser Ray Pathology and Deformities

Mallet Toe and Curly Toe

In case of a mallet toe the distal phalanx is flexed on the middle phalanx. The deformity may be flexible or rigid. The MTP joint and PIP joint are not involved. Most often the specific cause is unknown. Shoe wear can be a factor. Frequently the affected toe is longer than the other toes and the DIP joint might become flexed in shoes. It may result from trauma (similar mechanism to the finger) or arthritis (particularly

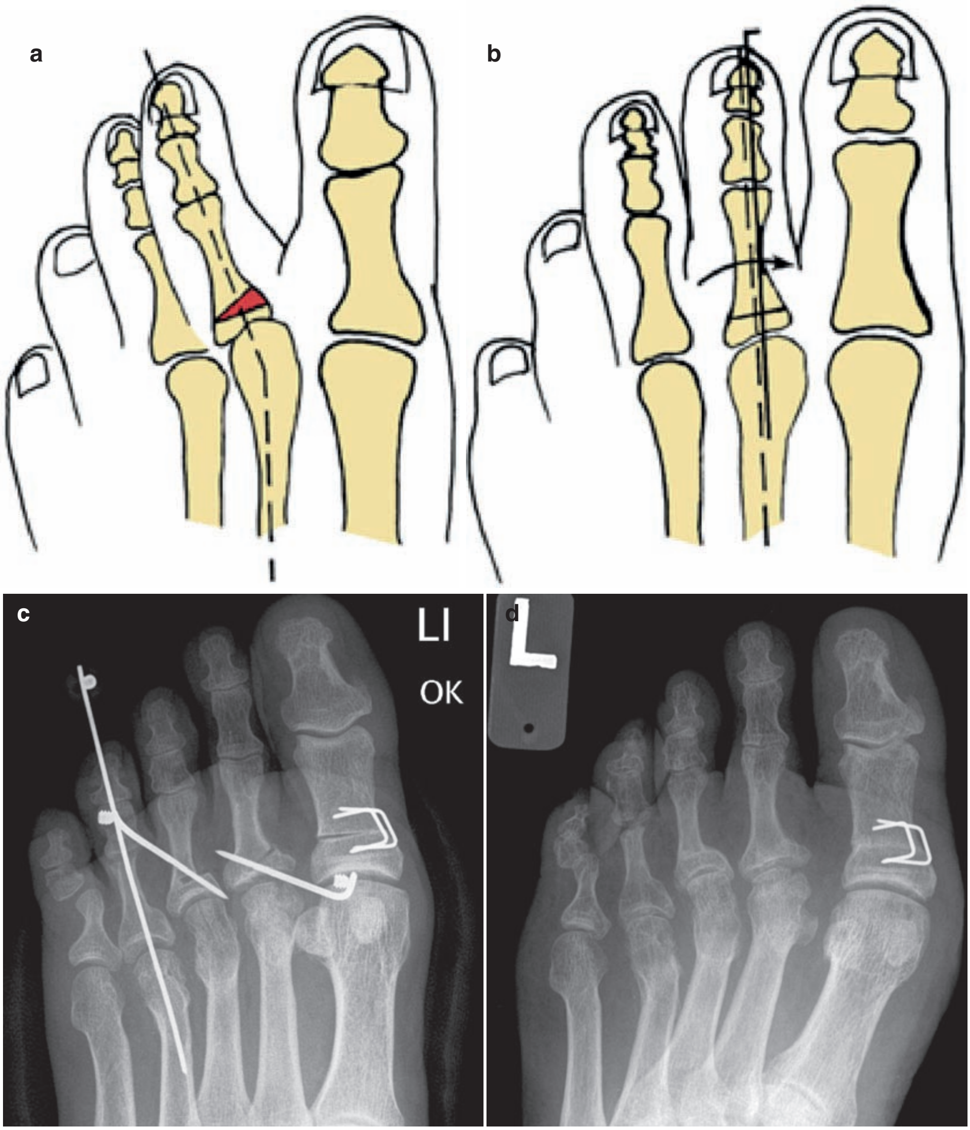

Fig. 21 (**a**, **b**) Illustration of wedge OT of the basal phalanx. (**c**) Direct post-operative situation. (**d**) One year post surgery, no recurrence

psoriatic arthritis) [29]. Persistent traction or shortening of the FDL tendon after previous PIP fusion procedure can also cause a mallet toe deformity. Most frequently the second ray is involved [10]. Symptoms can be pressure or pain at the DIP joint, but mostly patients experience pain at the distal aspect of the toes. Particularly at standing and during walking the toes are pulled to the undersurface. This can cause problems of the skin and/or toenail.

A flexible deformity can quite easily be solved by tenotomy of the FDL tendon. The situation of

Fig. 22 (**a**) 15 year-old boy with idiopathic mallet toe deformity of the second and third toe. (**b**) Same patient following DIP fusion of the second and third toes

a congenital curly toe is not really different from this and also here tenotomy of the long flexor tendon will usually suffice as treatment (Fig. 19).

In case of fixed flexion deformity at the DIP joint a corrective fusion is advised (Fig. 22). One can choose to perform this procedure through a Z-shaped dorsal incision or a reversed U-shaped incision. The joint is excised using an oscillating saw. As is the case with a PIP fusion one needs to excise just enough bone to correct the deformity. The joint can be fixated with dorsal sutures through the extensor and the skin, with external splinting applied after surgery, but commonly the joint is temporary fixated using an intramedullary K-wire. This K-wire does not need to cross the MTP joint. Some prefer to use a second K-wire to secure the distal toe against rotation, others trust on wound dressing and tape. Fusion needs 4, usually 6, weeks. Coughlin showed successful fusion rates in 72 % and pain relief in 97 % of cases after DIP arthroplasty [30].

Crossover Toe Deformity

A crossover toe usually concerns the situation in which the second toe deviates dorsomedially in reference to both the hallux and third toe. The second toe crosses over the hallux. This deformity often begins with pain at the second MTP joint due to a nonspecific arthritis of the second MTP joint. Overload as a result of hallux valgus complex is one of the common causes. Length of the second metatarsal and footwear have been described to play a role, as in hallux valgus. Laxity/instability results from chronic synovitis as also secondary muscular imbalance. The proximal phalanx extends progressively and the joint subluxates dorsally. Factors causing the medial deviation may be medial pull of the long flexor tendon and/or laxity of the lateral supporting joint structures [31]. In severe cases the MTP joint can become dislocated. The second MTP- joint is thought to be the most commonly dislocated joint in the foot [32]. This process at the second MTP joint seems to be very comparable with the process of progressive deformity as encountered at the MTP joints in patients with rheumatoid arthritis, except that then the MTP joints most often deviate laterally.

Basically the operative treatment is not different from a claw toe correction as described previously. A slight alternative is to reef the lateral capsule of the MTP joint. When performing this, first the suture(s) are placed, then the joint is re-positioned and fixed with a K-wire and then the sutures are tightened. The second ray is relatively shortened with release of tension through PIP resection. Of course the procedure should be combined with correction of alignment of the first ray in case of hallux valgus deformity in order to address the relative overload of the second ray with increase pressure under the second MT head.

In more severe cases even after stepwise release of all soft tissues and PIP resection it is necessary while testing reduction in the SP that the toe remains dorsomedially subluxed. One might decide to trust on fibrosis of the joint after a period of fixation in a corrected position to keep the joint re-aligned, but certainly when a relative overlength of the second metatarsal is found a shortening, Weil, osteotomy of this metatarsal should be considered (Fig. 23). Recently, Devos et al. reported association between crossover deformity and a relative lateral position of the second MT head and they advise to combine the shortening with translation of the second MT head [33]. It seems a very logical approach to re-align the metatarsal bone and the toe neutralizing the force of muscle force similar to our goals in hallux valgus surgery.

Overlapping Fifth Toe Deformity

The deformity usually consists of dorsiflexion contracture at the MTP joint with also an adduction and external rotation component of the fifth toe. These components typically cause the fifth toe to overlap the fourth. It is a quite common familial deformity, which causes disability in half of the affected patients [34]. In mild deformities a MTP joint release, as described by DuVries, may be satisfactory [35]. In more severe impairment the most applied procedure is the Butler s operation described by Cockin in 1968 [34]. The Ruiz-Mora procedure has been described as salvage procedure. Again, as in crossover deformity, the basic approach is identical with a claw toe correction. The same steps are applied starting with lengthening or tenotomy of the extensor tendons. In mild cases tenotomy and capsulotomy (DuVries technique) can be sufficient [34]. Recurrence is nearly always seen as a result of not lengthening or cutting the extensor tendon and secondary contracture of soft tissues. The step following capsulotomy is a further release of the joint, the collateral ligaments are sectioned and a curved elevator is used to release contracture at the plantar aspect of the MT head. PIP resection is performed to address the fixed deformity at the level of this joint and also for decompression. Commonly this suffices. Re-alignment should be tested with the foot in SP. Quite an amount of external rotation can be accepted.

In case the fifth toe remains extended and adducted additional measures are needed. Possibilities are to use the extensor tendon, releasing the tendon proximally and bringing it out of the wound distally, to pull the toe in a lateral plantar direction and attaching it to the abductor [36]. Another possibility is to excise an elliptical amount of skin at the lateroplantar aspect of the joint. Once all steps of claw toe correction have been performed then temporary closure of the skin should be able to keep the toe in corrected position. The skin is sutured after re-aligning and fixing the toe, the MTP joint in slight plantarflexed overcorrection, with a K-wire. The K-wire is removed after 6 weeks and hereafter further splinting can be applied with tape or bandaging. In our experience no special skin incisions are necessary at the dorsal aspect of the fifth ray. Just as in all claw toe corrections slightly curved or straight longitudinal skin incisions provide good results without residual contracture due to the skin. As pointed out above the cause of residual deformity is commonly the extensor tendon still pulling the toe in extension or insufficient release of the hyperextended MTP joint. A definite salvage, but in our view, very rarely indicated procedure, is the Ruiz-Mora procedure [37, 38]. This procedure comprises amputation of the proximal phalanx with soft tissue interposition, through a plantar incision.

Toe Corns

Corns and callosities (Figs. 20b, 24 and 25) are some of the most prevalent foot problems in older people, affecting 20 65 % of people aged > 65 years of age [39]. They can lead to considerable pain and disability. The prevalence is higher among women, most likely to be associated with footwear. Often hallux valgus deformity plays a role in this process causing increased pressure. The development of callosity is

Fig. 23 (**a**) Crossover position of the second toe and hammer toe 3rd ray. (**b**) Radiograph before surgery. (**c**) Following mild shortening and translation osteotomy of MT2 and PIP resection 2-3. (**d**) Good clinical result

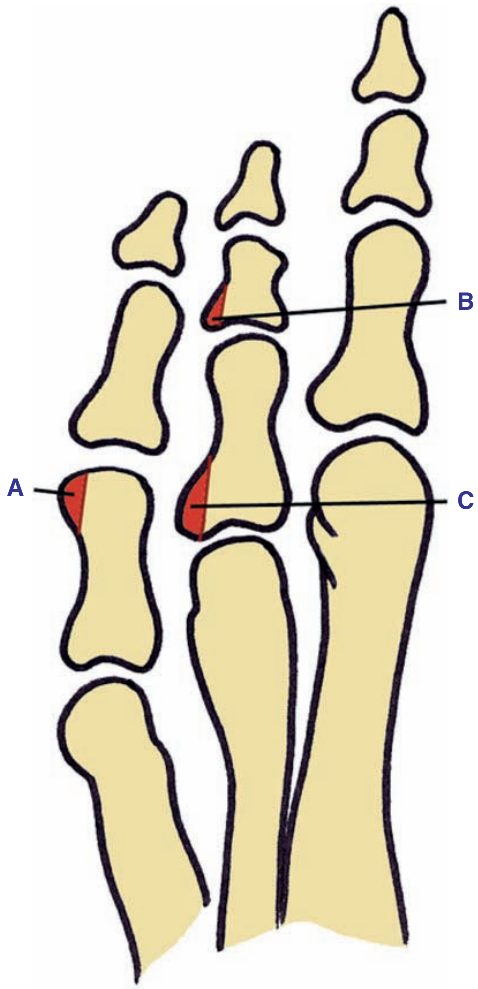

Fig. 24 Nomenclature for corns as introduced by Coughlin. A, lateral fifth toe corn. B, interdigital corn. C, Web space corn

associated with increased local pressure [40, 41]. In response to repetitive friction or pressure, normal skin undergoes changes, resulting in increase of thickness, with a considerable amount of hyperkeratosis [40]. A nomenclature for corns has been introduced by Coughlin (Fig. 24) [42, 43]. Typically the corns can develop at the lateral aspect of the fifth toe or between the toes where condyles of the heads of one toe can be

Fig. 25 Example of a web corn

pressed against the bases of the metatarsals and phalanges of the adjacent toe. These prominences are nearly always normal and only very seldom are we dealing with a true exostosis. These corns can be hard, but sometimes the pressure results in maceration of the tissue and then the term soft corn is used. Such a soft corn is easily confused with mycotic infection.

As described previously corns can also develop at the dorsal aspect of the IP joints or at the tip of a toe depending on the type of deformity. Footwear, padding and orthotics can relieve the pressure points. Removing the corn or the callus can give enormous relief. The presence of callosity itself creates an increase of pressure and consequently removing the callus seems wise also from a causative point of view.

Operative treatment is very rewarding and should be focussed on relief of the pressure. The problem, thus, should be solved from a biomechanical point of view. This might imply a simple tenotomy, a partial condylectomies and/or complete condylectomies.

Complications

Lesser toe corrections are often considered as simple surgical procedures, but it is said that patients that return after this type of surgery complain most. This complaint can be something that seems not so important like one toe still being rather long as compared with an adjacent toe. It is

Table 4 Outcome after different methods of PIP joint fusion

Author(s) technique	Number of patients or toes	Follow-up (average)	Residual pain	Malalignment	Satisfaction
Newman and Fitton [45]	15-resection	2.63 years	NR	10 % (no reported difference among three techniques)	32 %
Various	15-resection with Kirschner wire fixation				40 %
	15-peg and socket				66 %
Alvine and Garvin [48] peg and socket	27 patients (75 toes)	NR	NR	NR	87 %
Lehman and Smith [49]	76 patients (137 toes)	1 year minimum	31 % dissatisfied	23 % dissatisfied	48 %
Machined peg and socket			44 % satisfied with reservation	29 % satisfied with reservation	37 % reservation
Coughlin et al [50]	63 patients (118 toes)	61 months	8 %	14 % patient rated	84 %
Resection with wire fixation				21 % by radiographs	10 % reservation

estimated that in the USA yearly more than 300,000 lesser toe operative procedures are performed. The outcome, in a minor to major degree, is disappointing in more than 16 % of the cases resulting in 50,000 unhappy patient toes a year [5].

Infection of the wound, pin tract infection, delayed union, non-union, floating toe, flail toe, recurrence [22], residual numbness, lack of toe purchase, K-wire breakage, reflex sympathetic disorder, post-operative scar contracture, deviation of the toe in the transverse plane, shoe wear restrictions, residual oedema, shortening, haematoma, prolonged swelling, stiffness are all known complications of toe corrections.

When performing a PIP arthroplasty it is important not to remove too much or to little bone. Non-unions of the PIP joint arthrodesis are mostly asymptomatic. Nevertheless patients do present with a painful pseudo-arthrosis of this joint. The outcome after different methods of PIP joint fusion is summarized in Table 4 [44].

Excessive bone resection causes a lack of stability and structural integrity of the toe and results in a flail toe. In our experience this typically occurs after resection of the base of the basal phalanx and more certainly after resection of large parts or the whole basal phalanx. By removing this piece of bone the plantar plate and herewith an important limb of the plantar aponeurosis are detached.

A more common complication is the loss of ability of one or more toes to purchase the weight-bearing surface in stance or walking, defined as the floating toe syndrome [46]. This can be caused by soft tissue imbalance in which case the deformity is flexible. It is attributed to relative overlengthening of the flexor tendons and dysfunction of the plantar plate. However, it is most often due to the combination of stiffening of the toe with hyperextension of the MTP joint. This hyperextension can be caused by contracture of this joint or through shortening/contracture of the soft tissues and/or extensor tendons. The conservative management consists of taping, orthotics and physiotherapy. The surgical treatment in case of persistent complaints consists of dorsal release of all contracted soft tissues and re-alignment of the still present phalangeal bones. If necessary tenodesis using flexors to hold down the basal phalanx has also been reported.

Fig. 26 (**a**) Reumatoid arthritis deformity before surgical correction. (**b**) Same patient after MTP1 fusion and claw toe correction. (**c**) Due to loss of extension of the MTP3 joint an overload arises at the distal end of the basal phalanx

Stiffening of the toe in a too straight position can be a factor of complaints and it is advised by some to after treat the toes in a more natural slightly curved position (comparable with adjacent toes) using special splintage and no K-wires [47]. An alternative is to slightly manipulate and bend the toe and wire after K-wire fixation. This does not give any problems at the time of removal of the wires.

K-wire breakage occurs at the level of the MTP joint as a result of metal fatigue due to continuous movement at this joint in the weeks following the surgery. An inadequate after- treatment shoe, poor instructions to the

Fig. 27 Necrosis of the third toe

patient, poor understanding of these instructions and such can be involved. We more often encounter breaking of K-wires in patients with sensory neuropathy and these patients should be instructed more extensive or the use of K-wires in this patient group should be avoided.

Two types of complications concerning claw toe correction as described in this chapter should be discussed. The first problem can be post-operative stiffness of the MTP joint after release and K-wire immobilization. The joint is in principle positioned in a slight plantarflexed position. In cases with a severe diseased MTP joint, for instance as a result of rheumatoid arthritis, this treatment regime can result in stiffness of the joint with loss of extension. When this does not resolve with physiotherapy in time extension of the toe may start to take place at the PIP level. This is accompanied with increase pressure at the plantar aspect of the distal end of the basal phalanx. A callosity can arise and patients have residual complaints (Fig. 26).

Another complication that is encountered is disturbance of blood supply to the toe as a result of prolonged constriction and/or pull on the vessels as a result of lengthening. As soon as this is suspected the K-wire should be removed to release tension on the blood vessels. When this happens too late or if this complication is not acknowledged this can result in minor to major degrees of necrosis of the toe (Fig. 27).

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CURRICULUM VITAE

Joost Cornelis Schrier was born on the 24th of June 1978 in Nijmegen, the Netherlands. In 1997 he graduated from the VWO Pax Christi College in Druten. Thereafter, he started at the medical faculty of the Maastricht University. During this study he became interested in orthopaedic surgery. In 2003 he participated in an orthopaedic research programme at the Sunnybrook Health Sciences Centre in Toronto, Canada. In 2003 he finished his medical studies and became MD.

He started his carreer with a four month trip, with two friends, Jeroen en Remy, to South Eath Asia South-East Asia and New Zealand. After his return he started as nonspecializing resident in general surgery/orthopaedics at the Flevoziekenhuis in Almere. In 2006 he started a research project at the Isala Ziekenhuis in Zwolle, which meant the actual start of this PhD project.

He started his specialisation in orthopaedic surgery in 2007 at the Department of General Surgery of the Spaarneziekenhuis, Hoofddorp (dr. G.J.M. Akkersdijk). From 2009 to 2010 his orthopaedic training continued at the Deventer Ziekenhuis (dr. A.F.W. Barnaart). Subsequently he completed his academical training at the UMCG, from 2010 to 2011 (Prof. dr. S.K. Bulstra). He ended his specialisation programme at the Isala Klinieken (dr. C.C.P.M. Verheyen), from 2011 to 2013.

After finishing his specialisation programme, Joost went for an AO Trauma fellowship to the Kantonsspital Luzern (Prof. dr. R. Babst) in Switserland. After his return he fulfilled a 6 month period as Chef de Clinique at the Canisius Wilhelmina Ziekenhuis, at the end of 2013. From January 2014 he started as fellow at the Foot and Ankle Reconstruction Unit at the Sint Maartenskliniek in Nijmegen (dr. J.W.K. Louwerens). In July 2014 Joost acquired a definitive position at the Medinova Klinieken in Breda, focusing on foot/ankle surgery, hip arthroplasty, knee arthroscopy and patellofemoral pathology.

Currently he lives with his dearest Willemijn, and two lovely daughters Roos and Liselot, in Breda.